Cover

West Virginia's Technology Blueprint: Gap Analysis and Identification of Strategic Technology Platforms

Prepared for:
West Virginia Vision Shared Technology-Based Economic Development (TBED) Team

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Technology Partnership Practice

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Table of Contents

List of Figures

List of Tables

Abbreviations

BLS	U.S. Bureau of Labor Statistics
BRNI	Blanchette Rockefeller Neurosciences Institute
CEO	Chief executive officer
CITeR	Center for Identification Technology Research
CJIS	Criminal Justice Information Services
DoD	U.S. Department of Defense
DOE	U.S. Department of Energy
EDGE	Economic Development Generating Excellence
ELS	Entrepreneurial League System
EPSCoR	Experimental Program to Stimulate Competitive Research
FBI	Federal Bureau of Investigation
FY	Fiscal year
GSP	Gross state product
IP	Intellectual property
IUCRC	Industry/University Cooperative Research Center
IV&V	Independent Verification and Validation
JIT	Jobs Investment Trust
MATRIC	Mid-Atlantic Technology, Research, and Innovation Center
MTI	Maine Technology Institute
MU	Marshall University
NASA	National Aeronautics and Space Administration
NBSP	National Biometric Security Project
NETL	National Energy Technology Laboratory
NIH	National Institutes of Health
NIOSH	National Institute for Occupational Safety and Health
NIST	National Institute of Standards and Technology
NSF	National Science Foundation
NTTC	National Technology Transfer Center
QCEW	Quarterly Census of Employment and Wages
R&D	Research and development
SBA	U.S. Small Business Administration
TBED	Technology-based economic development
TTO	Technology Transfer Office
WJU	Wheeling Jesuit University
WVHTC Foundation	West Virginia High Technology Consortium Foundation

Executive Summary

To compete in today's global economy, a state must have sources of innovation and technology, a talent base of knowledge workers, and capital markets that are receptive to innovative firms and entrepreneurs that develop and apply cutting-edge technology to create new products and processes. Those states and regions with an economic base composed of firms that constantly innovate and maximize the use of technology in the workplace will succeed in growing a technology-based economy.

Historically, West Virginia has had an economy built on energy, chemicals, and natural resources. A decade or more ago, public and private leaders began to build the infrastructure that would support innovation and knowledge-based industries, help to diversify the state's economy, and provide high-wage jobs for its citizens. West Virginia, with support from its congressional delegation, attracted a number of federal and nonprofit research and development (R&D) centers; and a number of initiatives were launched to promote the development of the state's technology sectors. Investments built up the R&D capabilities of both West Virginia University (WVU) and Marshall University (MU). These investments are nurturing technology-based companies in the state; but, West Virginia continues to face challenges in growing its technology industries and transitioning its economy to one based on innovation.

West Virginia's Federal and Nonprofit Technology Anchors

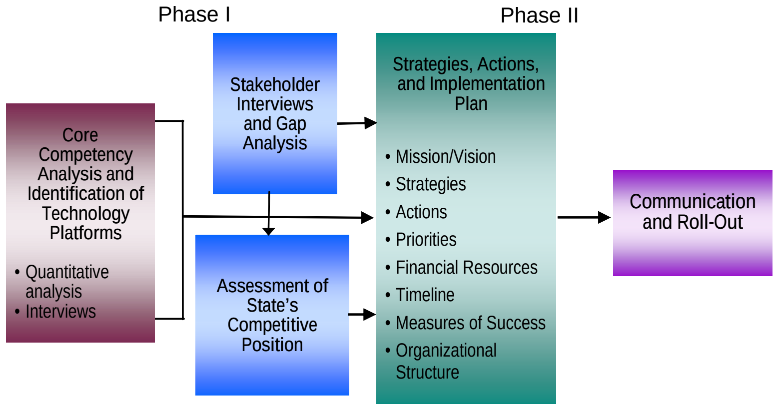
- DoD Biometrics Fusion Center
- FBI Criminal Justice Information Services Division
- MU Forensic Science Center
- Mid-Atlantic Technology Research and Innovation Center (MATRIC)
- NASA Independent Verification and Validation Facility
- National Biometric Security Project
- National Energy Technology Laboratory
- National Institute for Occupational Safety and Health
- National Technology Transfer Center
- Rahall Transportation Institute
- U.S. Army Corps of Engineers
- West Virginia High Technology Consortium (WVHTC) Foundation

The Vision Shared Technology-Based Economic Development (TBED) Team, created to determine how to achieve the goals laid out in West Virginia's Economic Development Strategy, *West Virginia: A Vision Shared!*, is preparing a West Virginia Technology Blueprint to identify the specific strategies and actions that should be undertaken to ensure that West Virginia continues to grow its technology companies by leveraging and continuing to enhance its R&D assets and ensuring that the talent and infrastructure are in place to support technology-based development.

As a first step in developing the Blueprint, The Vision Shared TBED Team engaged Battelle's Technology Partnership Practice (TPP) to assist it by (1) identifying specific gaps that will need to be addressed in the Blueprint and (2) recommending specific technology platforms around which West Virginia's technology economy may be built. Battelle's TPP, which includes leading analysts and practitioners in technology-based economic development, helps clients develop, implement, and evaluate technology strategies, policies, and programs.

PROJECT METHODOLOGY

Figure ES-1: Development of West Virginia's Technology Blueprint

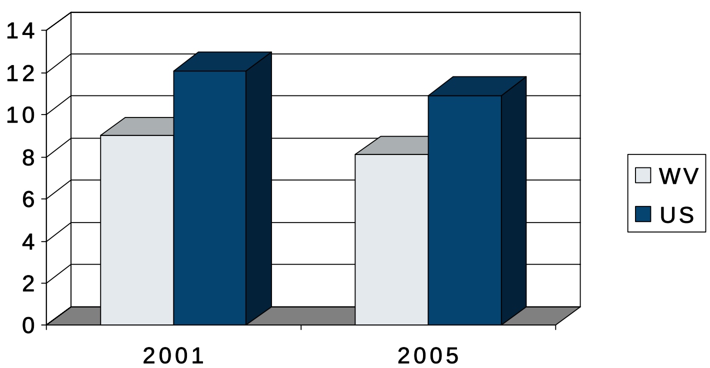


The West Virginia Technology Blueprint is being developed in two phases. Phase I, the subject of this report, included review of secondary data and interviews with key public and private leaders to assess West Virginia's competitive position and to identify gaps to be addressed in the Blueprint. Battelle also conducted quantitative and qualitative analyses to assess West Virginia's research core competencies and identify technology platforms or areas that offer the greatest potential for West Virginia's future economic growth (Figure ES-1). The results of Phase I provide the basis for proceeding with Phase II, which includes developing specific strategies and actions and an implementation plan.

KEY FINDINGS

West Virginia's technology industry base is growing but has yet to reach critical mass. In 2005, 8.1 percent of West Virginia's private sector employment was in high-tech industries.[1] This compares with 10.9 percent nationally (Figure ES-2). Both nationally and in West Virginia, high-tech employment declined between 2001 and 2005. West Virginia's decline of 8.5 percent was, however, slightly lower than the U.S. decline of 8.7 percent.

Figure ES-2: Percent of Total Employment in High-Tech Industries, West Virginia and United States, 2001 and 2005



Source: U.S. Bureau of Labor Statistics (BLS) and Battelle calculations.

[1] High-technology industries include those sectors identified by the BLS as having a significant core of occupations highly related to technology. An industry is considered high tech if employment in technology-oriented occupations (scientists, engineers, and technicians) account for a share of total employment that is at least twice the 4.9 percent average for all U.S. industries. BLS further breaks down the industries into three Levels. Level I includes industries in which technology-orientated occupations account for a share at least five times the average. Level II includes industries with 3.0 to 4.9 times the average, and Level III includes 20 industries with a share 2.0 to 2.9 times the average.

The I-79 corridor in North Central West Virginia experienced significant growth of its high-technology sector between 2001 and 2005. This region (Monongalia, Marion, Harrison, and Lewis Counties) has a location quotient (LQ) [2] of 1.04, meaning that it has a slightly higher concentration of high-tech employment than the nation. As a result of the rapid growth of the region‘s high-technology sector, its LQ increased from 0.74 to 1.04 between 2001 and 2005. Statewide, West Virginia has a 26 percent lower concentration in high-tech employment than the nation, with an LQ of 0.74.

While West Virginia does not have a specialization in the overall high-tech sector, the state does have specializations (defined as LQs of 1.2 or greater) in technology industry sectors that are growing. These include oil and gas extraction, in which employment grew almost 20 percent between 2001 and 2005, and pharmaceutical and medicine manufacturing, which grew 67 percent in employment during the same time period. It should be noted, however, that the pharmaceutical and medicine manufacturing sector includes only five establishments[3]; thus, this growth has been concentrated in a small number of companies. West Virginia is very specialized in pipeline transportation of natural gas; resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing; and basic chemical manufacturing; but, all of these industries experienced employment declines between 2001 and 2005. Aerospace products and parts, while not yet a specialization, is approaching one. Employment in this sector grew 20 percent between 2001 and 2005.

Competitive Advantages

- Presence of a large number of nonprofit and federal research institutions
- Growing academic research base
- Increased focus on tech transfer and commercialization at MU and WVU
- Growing technology sector, particularly in North Central West Virginia
- Highly productive workforce
- Quality college graduates
- Growing entrepreneurial support infrastructure
- Quality of life that is attractive to many people

West Virginia also has a number of potential emerging high-tech industries. Several industries in which West Virginia does not have a concentration are growing faster in the state than in the nation. Data processing, hosting and related services; computer systems design and related services; management of companies and enterprises; management, scientific and technical consulting; and architectural engineering and related services all experienced at least 10 percent growth in employment between 2001 and 2005; and each grew faster than their respective industry at the national level. Most of these sectors have a significant number of establishments, suggesting that they are composed of smaller companies; and most experienced an increase in the number of establishments between 2001 and 2005, suggesting that these are areas of entrepreneurial activity in West Virginia.

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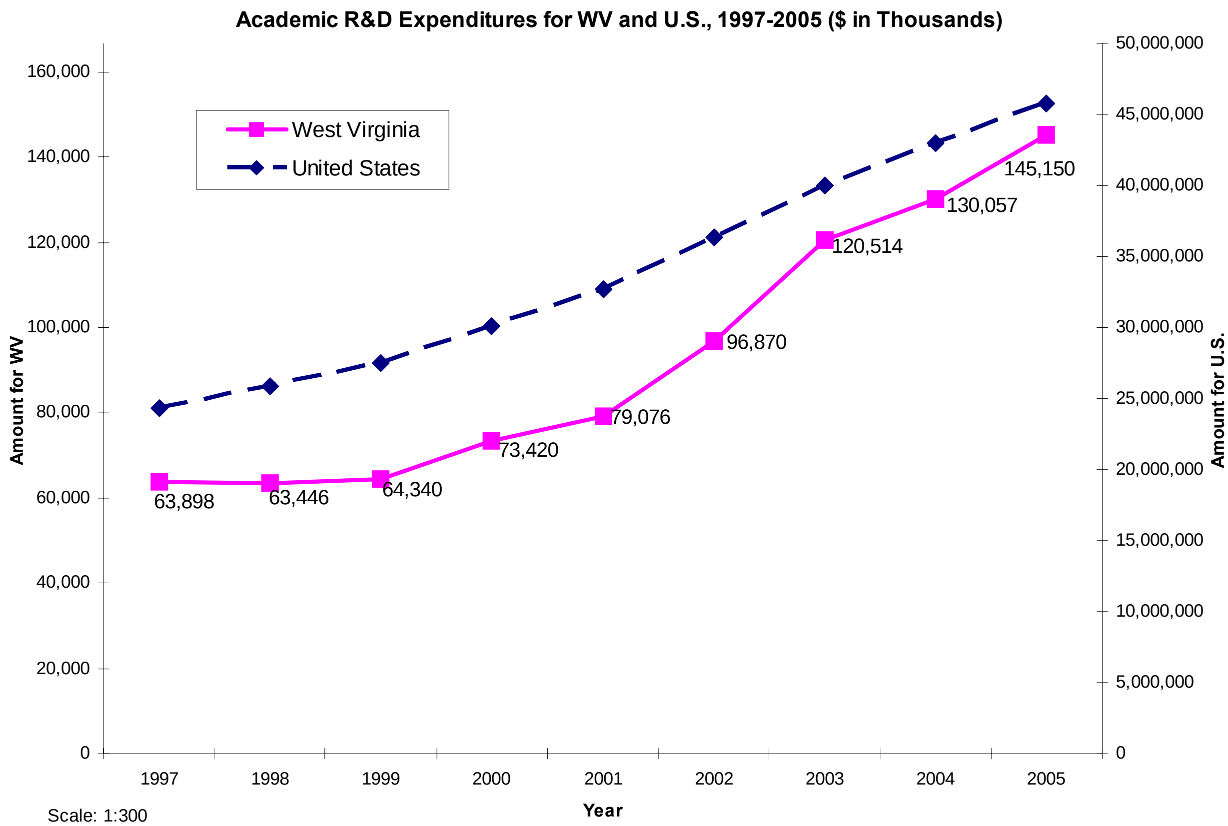
[2] LQs are a standard measure of the concentration of a particular industry in a region relative to the nation. The LQ is the share of total employment in the particular industry divided by the share of total industry employment in the nation. An LQ greater than 1.0 for a particular industry indicates that the region is relatively concentrated, whereas an LQ of less than 1.0 signifies a relative under- representation. An LQ greater than 1.2 denotes employment concentration significantly above the national average and is referred to as a “specialization.”

[3] An establishment is a place of business. If a corporation has more than one location in the state, each location would be counted as one establishment.

West Virginia has a growing R&D base driven by its federally funded R&D centers that is competitive with many of the benchmarks[4]; but, the state trails the benchmarks in terms of academic and industrial R&D. West Virginia ranked fifth among the benchmarks in terms of total R&D expenditures (expenditures from academic institutions, industry, federal organizations, federally funded research and development centers, and nonprofit centers), which totaled $538 million in fiscal year (FY) 2003. West Virginia ranked third, however, behind only Idaho and Tennessee, when taking into account the size of each state's economy as measured by dollars of R&D per dollars of gross state product (GSP). R&D accounted for 1.15 percent of West Virginia's GSP. On a per capita basis, West Virginia ranked behind only Tennessee and Idaho among the benchmark states, at $297 in per capita R&D. West Virginia ranked fifth in terms of academic R&D expenditures behind Idaho, Kentucky, Oklahoma, and Tennessee. Only Arkansas ranked lower than West Virginia in terms of per capita industrial R&D spending.

West Virginia's universities have experienced significant growth in their R&D activities, outpacing growth in academic R&D nationally. Total academic expenditures in West Virginia were approximately $145 million in 2005 and have been growing at a pace that exceeds that of the nation, increasing by 85 percent between 2001 and 2005 as compared with 40 percent nationally (Figure ES-3).

Figure ES-3: Academic R&D Expenditures, West Virginia and United States, 1997–2005 ($ in thousands)

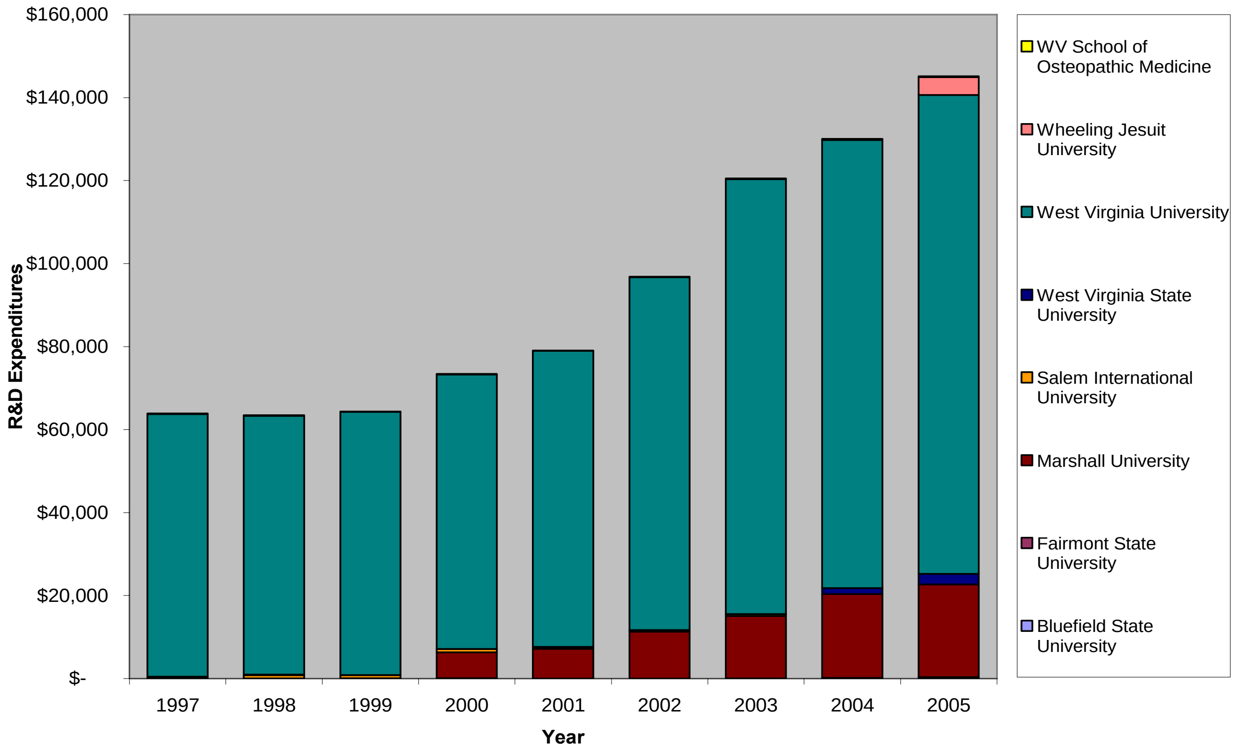


Source: National Science Foundation (NSF) Academic R&D Expenditures, 2005; Battelle calculations.

[4] On selected measures, Battelle compared West Virginia to six benchmark states—Arkansas, Idaho, Kentucky, Maine, Oklahoma, and Tennessee. These states were selected because they share similarities to West Virginia in terms of size and makeup of their industrial base or because they are actively implementing policies and programs to grow their technology sectors.

The overwhelming majority of academic R&D expenditures in West Virginia is contributed by two schools—WVU and MU—and both continue to invest in growing their respective R&D enterprises (Figure ES-4). Of note, MU's level of academic expenditure has increased dramatically in recent years, from less than $1 million in 1999 to upward of $20 million in 2004. And both WVU and MU continue to invest in new infrastructure and personnel. Both Wheeling Jesuit University and West Virginia State University increased their R&D funding in 2005 as well.

Figure ES-4: Academic R&D Expenditures by West Virginia School, 1997–2005 ($ in thousands)



Source: NSF Academic R&D Expenditures, 2005; Battelle calculations.

West Virginia's research institutions do not appear to be strongly linked to industry. West Virginia's universities and colleges received only $4 million out of a total of $130 million in R&D funding from industry in FY 2004, although the $4 million was a significant jump from the $2 million received from industry in FY 2003.

Both MU and WVU, however, have made recent commitments to promoting commercialization and supporting start-up and emerging companies. MU recently created a Technology Transfer Office (TTO) whose mission is to "make the unique products and services generated by our faculty, staff, and students available to the public for commercialization."[5] The MU TTO is working with local economic development organizations to provide support to its start-up companies. WVU created its Office of Technology Transfer in 1999 and since then has been focusing on both growing WVU as a research institution and linking it to economic development. WVU has a business incubator and is developing a research park, with work about to begin on an initial 66,000-square-foot building that will include wet-lab–equipped incubator space and multitenant space. Both MU and WVU are making progress in spinning off new companies based on discoveries made in the universities.

[5] http://www.marshall.edu/tto/.

West Virginia has a highly productive workforce. Interviewees across the board stated that one of the greatest strengths of West Virginia is its workforce, which was described as hard-working, honest, innovative, and talented. The workforce of the Toyota plant in Buffalo, West Virginia, which has consistently ranked as the most productive auto engine plant in the nation, was cited as an example of this strength.

> West Virginia's underperformance in educating its young population could limit the state's access to a competitive workforce and weaken the economy over time. Compared with other states, relatively few 9th graders graduate from high school in four years and enroll in college by age 19. In addition, West Virginia trails other states in providing college-level training opportunities for working-age adults.
>
> *Measuring Up 2006: The State Report Card on Higher Education*
>
> The National Center for Public Policy and Higher Education, 2006

Employers interviewed also indicated that they are pleased with the quality of the graduates of West Virginia's colleges and universities, stating that they are usually able to hire entry-level engineers and other professional workers locally. Indeed, there are more quality graduates than there are employment opportunities for them.

Overall, however, the population is not highly educated, making it difficult to find highly skilled technical people and to attract technology companies that might consider a location in West Virginia. Only 16.9 percent of West Virginians 25 years or older have completed a bachelor's degree, compared with 27 percent nationally. And while West Virginia increased the percentage of 18- to 24-year-olds with a high school credential from 83 percent to 87 percent between 1992 and 2006, this is still below the high school completion rate of 94 percent in top performing states.

Young, single, and well-educated people, a potential source of talent, are out-migrating from West Virginia for want of good employment opportunities. Between 1995 and 2000, West Virginia experienced a net out-migration of 4,691 individuals aged 25 to 39 who were single and held at least a bachelor's degree.[6]

West Virginia's entrepreneurial support infrastructure is expanding. Statewide and regional programs are assisting entrepreneurs and emerging companies, including WVHTC Foundation's INNOVA program, a commercialization assistance program launched in 2002, and the Entrepreneurial League System being organized by Advantage Valley in the Charleston and Huntington area. In addition, West Virginia has a small cadre of service providers—law firms, accounting firms, etc.—with staff experienced in working with entrepreneurs and start-up companies.

But, West Virginia lacks entrepreneurs with a track record of forming and growing successful new technology companies. Entrepreneurs reported that it is difficult to put together a management team for a new venture. Experienced chief executive officers (CEOs), chief operating officers, chief financial officers, and senior technical employees must be recruited from outside the region. Because entrepreneurial activity has been limited, there are few role models and few opportunities for technology entrepreneurs to interact. This lack of critical mass of entrepreneurs is compounded by geographic distance, although some regions are beginning to provide opportunities for networking.

West Virginia lacks a fully developed risk capital market able to meet the needs of technology firms at various stages of their product life cycle, particularly at the very early commercialization and pre-seed/seed stages, although the state has helped increase the availability of venture capital. West Virginia companies received only $14 million in venture capital investments between 1999 and 2006. Investors indicated that, to date, West Virginia has not had a pipeline of companies that have reached the stage at which they are considered investment grade.

[6] http://www.census.gov/population/www/cen2000/migration.html.

West Virginia does not have an organized angel investment community and has few sources of commercialization and pre-seed funding. WVHTC's INNOVA provides early-stage investment from $50,000 to $150,000; but, the total amount available for investment is only about $1.3 million, with $900,000 presently uncommitted. The West Virginia Jobs Investment Trust also invests in early-stage companies; but, again, resources are limited. WVU and MU have little access to resources to fund the proof-of-concept activities necessary to turn discoveries into technology with commercial applications.

West Virginia's recreational and lifestyle amenities make it an attractive location for many people. Again and again, interviewees indicated that natural beauty and high quality of life make West Virginia a very attractive place to live. The lower cost of housing, shorter commutes, and low crime rates attract workers tired of living in more congested metropolitan areas. CEOs indicated that there is a ready source of talent in terms of West Virginians who have left the state to pursue employment opportunities but who are anxious to return if they could obtain a quality job.

Challenges

- Small base of technology industry
- Low educational attainment of population
- Lack of entrepreneurial talent
- Insufficient sources of risk capital, particularly at the commercialization, pre-seed, and seed stages
- Lack of entrepreneurial and management talent
- Little regional collaboration because of both geography and tradition
- Conservative and risk-averse population
- Image of West Virginia inconsistent with a tech-based economy

Opportunities and How to Realize Them

Identifying West Virginia's Technology Opportunities

West Virginia is poised to diversify its economy by growing its technology sectors. Battelle's analysis identified the following opportunities that could be leveraged to achieve this:

- *Opportunities exist for greater commercialization of technology developed within the state's research institutions*. As West Virginia's universities continue to grow their R&D bases, a commitment to invest in and encourage commercialization of research findings could lead to an increase in the number of start-up companies.
- *The nation's increased focus on energy independence and alternative fuels is a tremendous opportunity for West Virginia* with its historic strengths in energy R&D and its strong energy industry sector. As home to the National Energy Technology Laboratory, West Virginia can take advantage of the resources of the NETL, as well as the strong energy R&D programs at WVU and the Rahall Transportation Institute at MU, to develop solutions to meet the nation's growing need for alternative energy sources.
- *West Virginia's lower cost of living and high quality of life could be used to attract technical talent and technology companies to relocate to the state.* West Virginia is close to the technology corridors in Northern Virginia and along I-270 in Maryland. As these regions become increasingly congested, West Virginia offers an alternative location that is still nearby existing clients.
- *West Virginia could attract additional federal operations that desire a secure location outside of, but close to, the Washington metropolitan area.*

- *West Virginia has a cadre of highly educated and experienced workers and R&D laboratories and facilities at the site of the former Union Carbide R&D headquarters that are available to grow a technology cluster in the greater Charleston region*.

Realizing the above opportunities will require significant investments to expand the state's R&D base and TBED efforts if West Virginia is to be competitive. Although a proposal is pending that would significantly increase West Virginia's contribution to its Research Challenge Fund, the state has, historically, not committed the same level of resources as its peer, competitor, and neighbor states to build an infrastructure to support technology companies. Even states with limited resources similar to West Virginia, such as North and South Dakota, are investing in state-supported centers of excellence and providing funding and support for commercialization.

Example of State investments in TBED

- **Kentucky's $350 million Research Challenge Trust Fund** created 111 endowed chairs and 179 endowed professorships that led to a 76 percent increase in university R&D
- **Maine** invested a total of $157 million to build its research base and promote commercialization
- **Ohio's Third Frontier Project** is a 10-year, $1.6 billion initiative to expand Ohio's research capabilities and promote innovation and company formation
- **Oklahoma's EDGE Endowment Fund** is a $1 billion fund to be created over a multiyear time frame to fund faculty recruitment, investment capital, and commercialization
- **Pennsylvania**'s proposed $850 million **Energy Independence Fund** is planned to make Pennsylvania a leader in clean energy

Realizing West Virginia's Technology Opportunities

West Virginia faces the following four key gaps in building its technology economy:

1. **Talent.** To accelerate the growth of its technology sectors, West Virginia must be able to recruit world-class researchers to its universities and research institutions, retain its talented graduates, upgrade the skills of its workers, provide training for technicians and production workers, encourage its high school graduates to continue their education, and ensure that students are well prepared in science and math at the K-12 level.
2. **Early-stage seed capital**. West Virginia has three capital gaps: (1) funding for translational research and commercialization in the range of $50,000 to $250,000 for proof-of-concept activities including preliminary market assessments, prototype development, and engineering optimization; (2) early-stage pre-seed and seed capital funding from $200,000 to $1 million; and (3) risk capital for companies that are not appropriate targets for venture capital financing because they are unlikely to provide the rate of return required by a venture capitalist, they have no exit strategy, or they need debt financing to cover operating expenses and equipment rather than equity but are unable to obtain conventional lending because they lack cash flow, collateral, and traditional assets.
3. **Entrepreneurial know-how.** West Virginia, historically, has not had an entrepreneurial culture with large companies dominating the state's economy. Any region without a track record of forming and growing successful technology companies lacks a supply of "serial" entrepreneurs, entrepreneurs who have both successfully and sometimes unsuccessfully started and grown several technology companies. As a result, there are few role models or experienced entrepreneurs to mentor aspiring entrepreneurs. Until West Virginia has a high churn rate of new-firm births and deaths, the state must find ways to attract, nurture, and support entrepreneurial and management talent. While several entrepreneurial support programs have been put in place, most of these organizations are resource poor and small scale. The challenge will be to organize these resources into a seamless commercialization assistance network.

4. **Image.** CEOs, representatives of higher education, and public and private leaders interviewed for this project expressed the same concern—negative stereotypes of West Virginia persist and impact the state's ability to raise capital, recruit talent, and attract technology companies. The lack of awareness of the technology assets of West Virginia exists not only in people unfamiliar with West Virginia, but with many West Virginians as well. Efforts will be needed to change this image, both internally and externally, and to better educate both policymakers and the general citizenry on the technology economy and West Virginia's role in it.

In summary, West Virginia has had great success in attracting federal R&D dollars and continues to build its academic and nonprofit research base. Investments in West Virginia during the past decade are increasing the number of technology jobs. But, while West Virginia is changing, perceptions are lagging and the state still faces major challenges in accelerating the growth of its technology economy.

West Virginia's resources are limited. Thus, it is important that, in addition to addressing these gaps, West Virginia focus strategically on those technology areas in which the state has a competitive advantage. The state's research strengths, core competencies, and the technology areas they suggest for focus are discussed below.

West Virginia's Core Competencies

Three tests can be used to identify a core competency:

1. Is it a significant source of competitive differentiation? (Does it provide a unique signature for the state?)
2. Does it transcend a single business? (Does it cover a range of businesses, both current and new?)
3. Is it hard for competitors to imitate? (Are there significant barriers to entry?)

From an economic-development perspective, core competencies represent a "critical mass" of know-how. It is through core competencies that a position in emerging technologies can best be gained.

West Virginia's Research Strengths

Battelle has developed a rigorous and robust approach to assessing a state's core competencies. It involves (1) an in-depth analysis of patent and federal grant awards, (2) a specialized cluster analysis that examines how grants and patents relate to one another, and (3) validation from interviews with industry executives and university officials.

Battelle's analysis of West Virginia's research funding, publications and citations, and patents showed that West Virginia has strengths in the following research areas:

- Energy and Energy-Related Technology
- Materials and Materials Science
- Chemicals and Chemical Engineering
- Computer Science and Associated Electronics Engineering
- Environmental Science and Ecology
- Neurology and Neurosciences
- Cancer
- Pharmacology and Toxicology
- Imaging
- Public Health and Occupational Health/Safety
- Psychology
- Plant Sciences

These areas are described in Table ES-1.

Table ES-1: West Virginia's Areas of Research Strengths Identified Through Quantitative Analysis

Areas Focused in Engineering and Physical Sciences				
Competency Area	**Publications/Citations Strength (ISI Data)**	**OmniViz™ Clusters**	**Major Funded Centers or Institutes**	**Notes**
Energy and Energy-Related Technology	Spread across multiple science and engineering disciplines. No specific ISI category Federal funding data show West Virginia more focused on engineering R&D than the nation as a whole	• Coal-related technologies • Oil- and petroleum-related technologies • Well drilling and boring technology • Fuel cells • Vehicles and transport devices	• NETL • National Research Center for Coal and Energy • Advanced Power and Electricity Research Center • Research Center for Alternative Fuels, Engines and Emissions • West Virginia Industries of the Future	Major fossil fuel emphasis: ➢ Resources ➢ Technology ➢ Efficiency ➢ Environment NETL with 407 full-time employees (FTEs) and $32 million local research budget ($259 million total)
Materials and Materials Science	• Applied physics/materials science • Polymer science	• Composites and advanced materials • Polymers • Chemicals and catalysts		Broad range of research focus areas—ranging from paving materials to nanomaterials 85 patents
Chemicals and Chemical Engineering	• Chemical engineering • Polymer science	• Chemicals and catalysts • Polymers		Strong industry R&D in chemicals and catalysts with 370 patents, and in polymers with 170 patents
Computer Science and Associated Electronics Engineering		• Information and communication technologies • Instruments, controls, and electronics	• WVNano • Center for Identification Technology Research	Major emphasis on identification technology, sensors, and nanotechnology 122 patents in instruments, controls, and electronics

Table ES-1: West Virginia's Areas of Research Strengths Identified Through Quantitative Analysis (continued)

Areas Focused in Biosciences				
Competency Area	**Publications/ Citations Strength (ISI Data)**	**OmniViz™ Clusters**	**Major Funded Centers or Institutes**	**Notes**
Environmental Science and Ecology	• Environment/Ecology • <50 papers, but influential in environmental engineering and energy; environmental medicine; environmental studies, geography and development	• Soil remediation	• NETL • WVU National Environmental Services Center • National Research Center for Coal and Energy • Center for Environmental, Geotechnical and Applied Science at MU • Research Center for Alternative Fuels, Engines and Emissions • West Virginia Water Research Institute	Major cross-disciplinary strengths Strong emphasis on fossil energy pollution control and environmental remediation technology
Neurology and Neurosciences	• Neurology • Neuroscience and behavior	• Drugs, diagnostics, and therapies • Cellular and molecular biology	• Sensory Neuroscience Research Center • Blanchette Rockefeller Neurosciences Institute • WVU Eye Institute	Long-term WVU strength, reinforced with recent investment in infrastructure and talent
Cancer	• Oncogenesis and cancer research • Pharmacology and toxicology	• Drugs, diagnostics, and therapies • Cellular and molecular biology	• WVU Mary Babb Randolph Cancer Center (signaling networks, tumor microenvironment, molecular therapeutics) • MU Cancer Biology Research Cluster • WVNano—signal detection/biomarkers	Multi-institutional capabilities stretching across WVU, MU, and WJU
Pharmacology and Toxicology	• Pharmacology and toxicology	• Drugs, diagnostics, and therapies • Cellular and molecular biology		Multi-institutional capabilities stretching across WVU and MU
Imaging	• Radiology, nuclear medicine, and imaging	• Imaging	• WVU Center for Advanced Imaging • WVU Virtual Environments Laboratory	MU developing visualization and imaging capabilities

Table ES-1: West Virginia's Areas of Research Strengths Identified Through Quantitative Analysis (continued)

Areas Focused in Biosciences (continued)				
Competency Area	**Publications/ Citations Strength (ISI Data)**	**OmniViz™ Clusters**	**Major Funded Centers or Institutes**	**Notes**
Public Health and Occupational Health/Safety	• Public health and healthcare sciences		• NIOSH Division of Safety Research, Division of Respiratory Disease Studies, Health Effects Laboratory Division • WVU Institute of Occupational and Environmental Health	NIOSH major presence with 369 FTEs and $36.1 million. R&D focus at WVU
Psychology	• Psychology			Multi-institutional strengths at WVU and MU
Plant Sciences	• Plant sciences	• Agriculture and food • Cellular and molecular biology		

To further investigate the fields identified in the quantitative analysis and deepen its understanding of the research core competencies in West Virginia, Battelle conducted extensive interviews with university administrators, faculty, scientists, clinicians, industry executives, federal laboratory personnel, and development agencies in the state. These interviews were essential in developing an understanding of how the data on publications, patents, and grant awards translate into on-the-ground focus areas in West Virginia.

The interviews partly confirmed West Virginia's research strengths identified in the quantitative analysis. They also highlighted several new and emerging areas of R&D and some key theme areas that were not readily apparent within the quantitative datasets. One challenge in using quantitative data is the rapid rate of change in the scientific enterprise. Peer review systems—whether used for federal grant awards, citation analysis, or in reputation rankings—tend to lag emerging new fields of inquiry and may fail to recognize the contributions of younger and new scientific talent. Therefore, one objective of the qualitative interviews was to capture emerging areas, faculty, and fields of inquiry at each of the subject institutions.

Based on the interviews, and in reference to the quantitative analysis, findings were organized into two basic levels:

Primary Established Strengths in which West Virginia has considerable presence through at least two of the following:

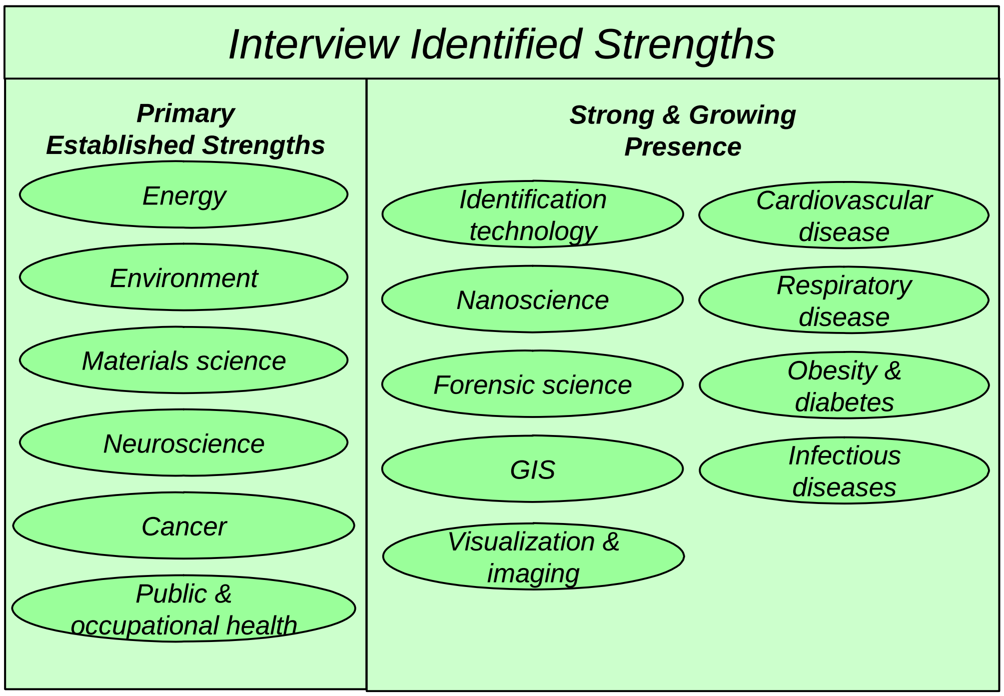
- A significant number of well-funded researchers, scientists, and/or clinician scientists working in basic or applied R&D
- Applied science R&D assisting critically important current and/or emerging commercial sectors
- A number of commercial enterprises with R&D or production facilities working on the delivery of products or services
- Recognized clinical expertise (in biomedical fields).

Strong and Growing Presence where West Virginia has demonstrated strengths that are more focused or one dimensional; have lower levels of research activity, clinical expertise, or commercial enterprises; or are more niche focused. In many instances, these include research areas required to support other areas of strength or to form platforms for economic development from science and technology. As such, these are highly important strengths to continue building.

Based on these general parameters, the project team identified the research competency areas shown in Figure ES-5.

It should be recognized that many of these strength areas are supported by considerable investment and expertise within multiple cross-cutting areas of science and technology. Strengths in basic science and engineering disciplines, and the underlying science and technology R&D infrastructure in the state, must be maintained and invested in for core competencies to be sustained and leveraged.

Figure ES-5: West Virginia's Research Strengths Identified in Interviews



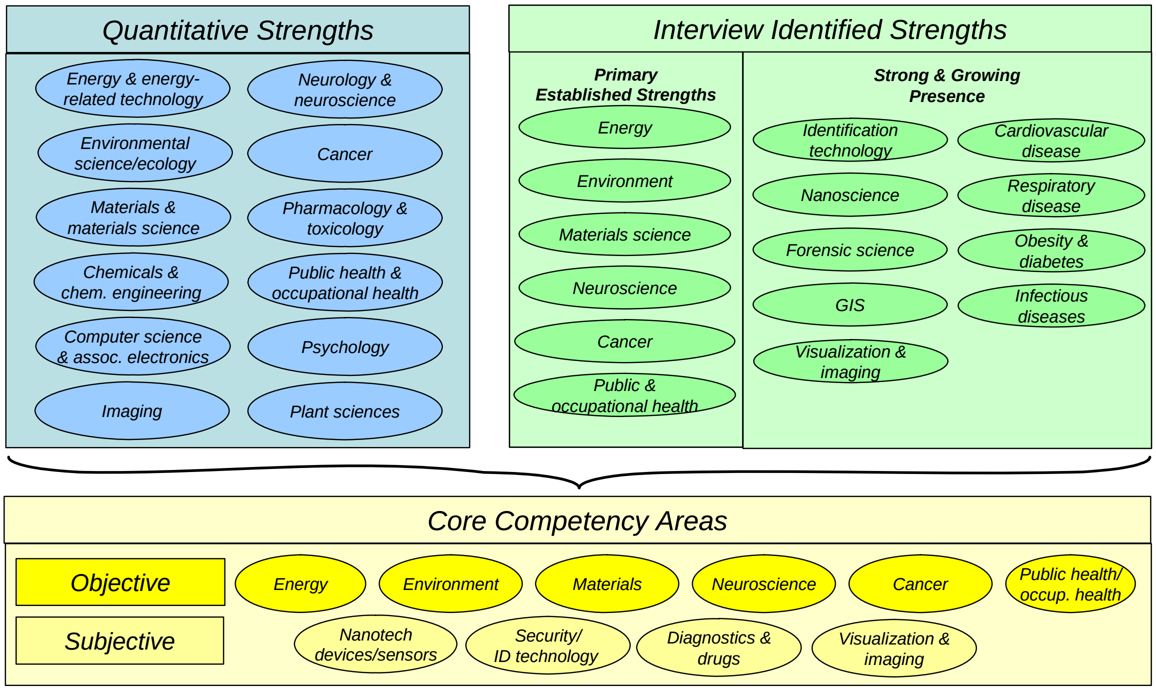
FROM STRENGTHS TO CORE COMPETENCIES

Referring to both the quantitative strength data and information derived from the interviews, Battelle identified general science and technology R&D core competencies in the state. Figure ES-6 provides a crosswalk of the quantitative and qualitative findings and identifies the research core competencies clearly suggested by these information sources.

The "objective" core competencies are those whose competency was sustained by information gathered in both the quantitative analysis and qualitative interviews. The project team determined the "subjective" competencies by examining the details of major R&D initiatives, cross-disciplinary research areas, and emerging areas that together form a logical technology core competency focus. Each core competency is described in detail in Appendix A.

These core competencies are the building blocks with which West Virginia's innovation-based economy may be built. Given these core competencies, the Battelle team proposed "technology platforms" that offer a competitive niche for West Virginia.

Figure ES-6: West Virginia's Research Core Competencies



TECHNOLOGY PLATFORMS, PRODUCTS, AND MARKET NICHES FOR WEST VIRGINIA

Identifying a state's research core competencies allows for identifying specific opportunities for growing a state's technology base around key technology niches or "platforms." But, research alone is not sufficient for ensuring technology development. Rather, the most likely areas for development in a region can occur where research intersects with a state's industry base, competitive advantages, and market opportunities.

Technology platforms serve as a bridge between the research core competencies and their use in commercial applications and products. They share the following characteristics:

- Are applications oriented, merging early-stage laboratory-scale science and technology into systems and devices. This process is called "fusion" or "convergence."
- Are robust and self-renewing to address current as well as new, emerging market opportunities.
- Produce a regular stream of innovative, perhaps disruptive, products (i.e., a product pipeline).

Criteria for Selecting Technology Platforms for Development

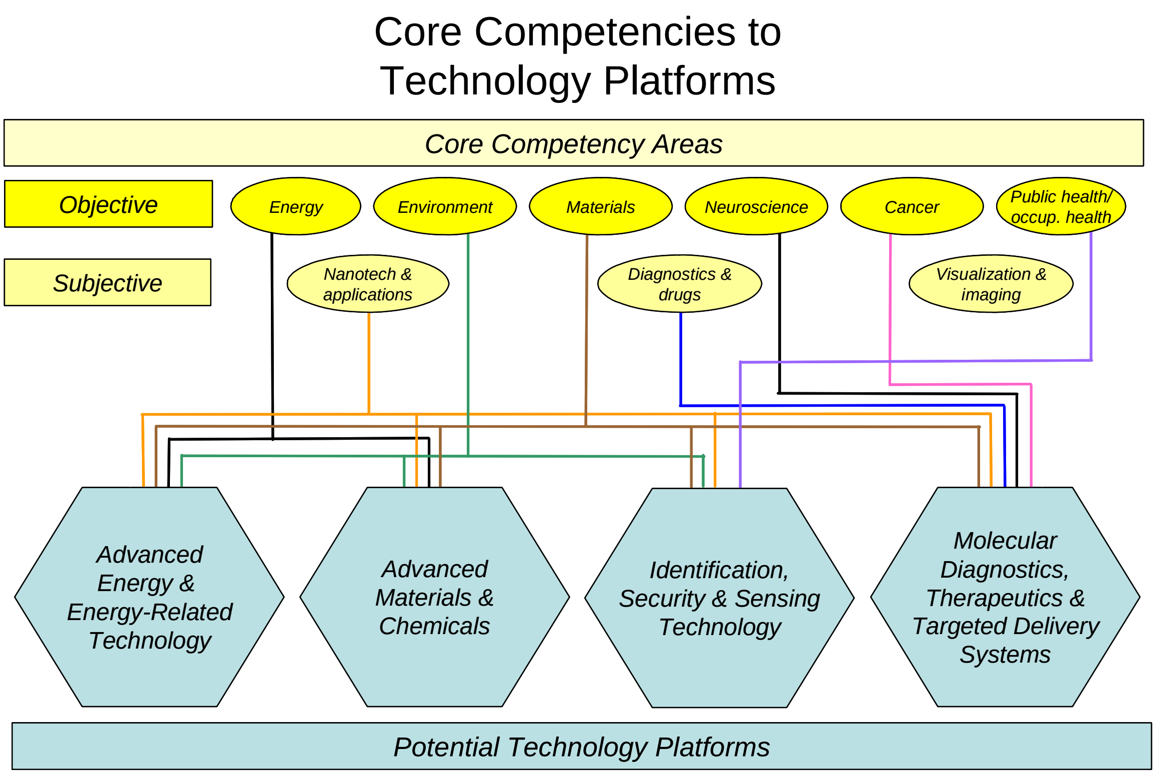
- Builds on existing strengths
- Has a base of related emerging or established commercial activity
- Provides opportunity to leverage state's comparative advantages
- Has significant product market potential
- Links or reinforces other strengths and core competencies

- Require cross-university and national laboratory collaborations—brand new teams as well as enhanced existing teams.
- Require partnership with industry to provide customer perspective and capacity to develop new products.

Based on Battelle's assessment, West Virginia's nine core competencies can be ordered into the following four technology platforms that could be sources of innovative technologies and products for West Virginia's economy (Figure ES-7):

- **Advanced Energy and Energy-Related Technology**
- **Advanced Materials and Chemicals**
- **Identification, Security, and Sensing Technology**
- **Molecular Diagnostics, Therapeutics, and Targeted Delivery Systems.**

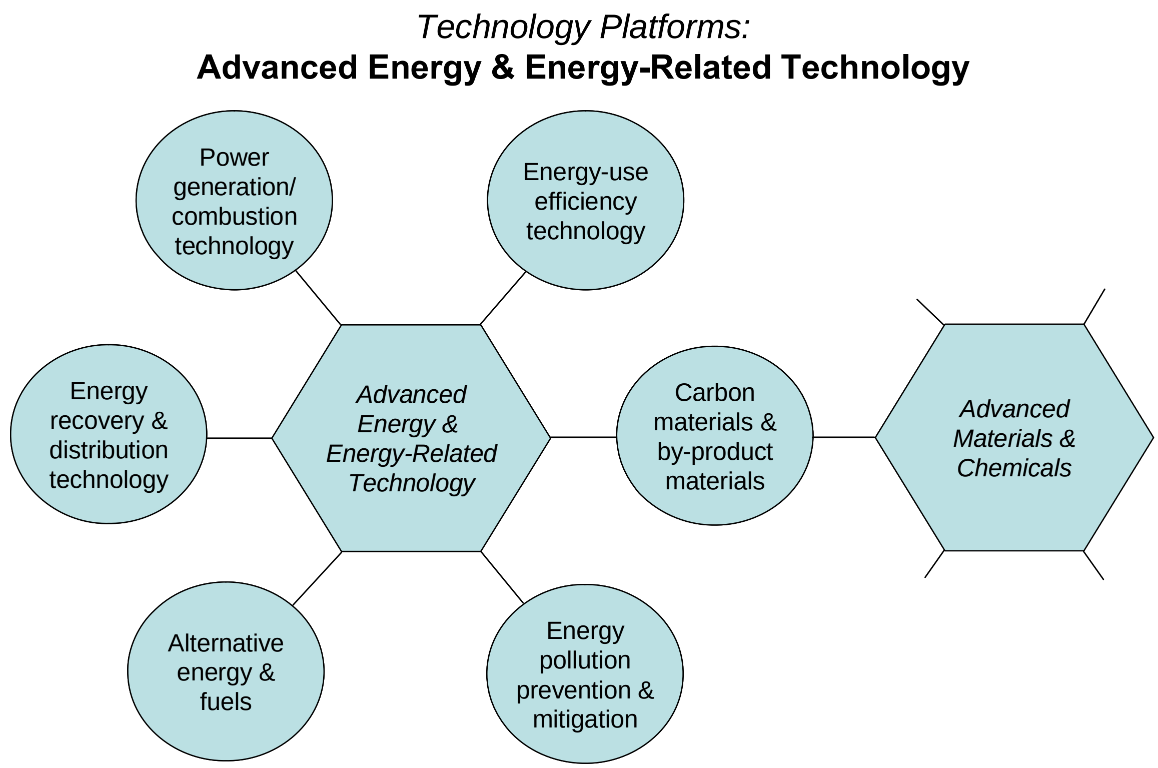
Figure ES-7: Proposed Technology Platforms for West Virginia



Advanced Energy and Energy-Related Technology

The alignment of West Virginia fossil fuel resources with advanced energy R&D in the state and growing domestic and global demand for energy provides West Virginia with an opportunity to **leverage energy as a platform for advanced technology development and economic progress**. Chief among the goals of such a platform should be to increase the value-added economic activity based on energy resources—developing high-value liquid fuels from carbon products, carbon-based chemicals, and advanced technologies for high-efficiency combustion, fuel conversion, pollution control, and energy transmission. Figure ES-8 illustrates opportunity areas for technology development from the recommended advanced energy and energy-related technology platform and also the cross-platform connectivity between the advanced energy and the advanced materials and chemicals platforms.

Figure ES-8: Overview of Advanced Energy and Energy-Related Technology Platform



The categories shown in Figure ES-8 represent key areas of opportunity for technology development from this platform. It should be noted, however, that the R&D expertise contained within the federal laboratory/university R&D complex in West Virginia is so broad that additional opportunities for technology development will no doubt present themselves. NETL has deep expertise in computational modeling and simulation that may well lead to commercializable technology development. Likewise, WVU maintains programs dedicated to servicing the research, training, and certification needs of industry in energy and transportation that may be leveraged for further development.

Advanced Materials and Chemicals

In addition to energy production, West Virginia has a strong track record in developing and producing chemicals and materials. The Kanawha Valley has been home to intensive chemical industry operations for more than a century, and the Ohio Valley in and around Parkersburg has a similar track record in the polymers sector. In materials, West Virginia has also enjoyed a strong presence in primary metals production and manufacturing operations, notably in the steel sector, but also in other metals and materials. Wood, a biorenewable material, also represents a significant economic resource for the state.

In 2004, six of the top 10 West Virginia manufacturing sectors were chemicals and materials related, including the following:

- Chemicals—$1.6 billion
- Wood—$642 million
- Primary Metals—$556 million
- Fabricated Metals—$463 million
- Nonmetallic Minerals—$328 million
- Plastics and Rubber—$286 million.

Combined, these six materials-related manufacturing sectors are responsible for over 70 percent of all West Virginia manufacturing output, demonstrating the importance of chemicals and materials to the West Virginia economy.

Clearly, maintaining the economic viability of the materials sectors is highly important to the economic sustainability of the state. R&D within industry, academe, and other research institutions within the state play an important role in securing a future for the West Virginia materials sectors. From an industry perspective, patent data illustrate the considerable volume of industry R&D taking place in these sectors within the state. The OmniViz™ cluster analysis recorded 625 patents issued between January 1, 2000, and April 2006 in "chemicals and catalysts," "composites and advanced materials," and "polymers."

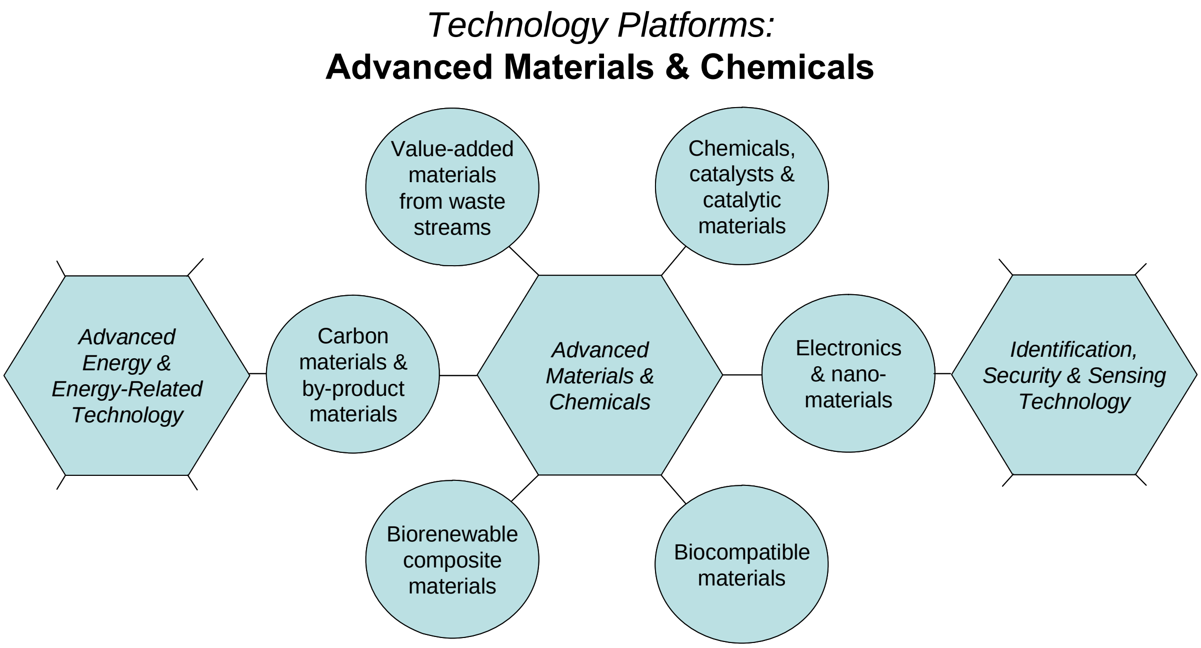
Within the R&D sector in West Virginia, interviews identified multiple areas of strengths in advanced materials and chemical technologies. R&D focus areas identified in the state show considerable attention being paid to advancing work in high-value materials such as the following:

- Electronics, semiconductor, and sensor materials
- Advanced composite materials
- Advanced polymers
- Catalysts and catalytic materials
- Products from West Virginia carbon, including carbon foams, anodes, and metal-casting materials
- Value-added wood products
- Nano and nanobio materials.

It is clear that the combination of West Virginia's existing industry base in materials and chemicals, coupled with significant R&D expertise relevant to the next generation of advanced materials and chemicals, provides the state with an opportunity for further development through an advanced materials and chemicals technology platform.

Figure ES-9 illustrates opportunity areas for technology development from the recommended advanced materials and chemicals technology platform and also the cross-platform connectivity between the platform and other recommended platforms.

Figure ES-9: Advanced Materials and Chemicals Technology Platform



Identification, Security, and Sensing Technology

The need for advanced security technologies based on the accurate identification of an individual has perhaps never been greater than it is today. National security concerns, in combination with the rapid growth of "identity theft" as a 21st century crime, are placing a strong imperative on the development of technologies that use biometrics, advanced sensors, and other technologies to certify the true identity of an individual. The need for such advanced technology is critically important for many applications, including, for example, banking and finance, health care and health insurance, government-issued identification such as driver's licenses and visas, and secure access to sensitive facilities and government installations. The market for such technologies will be extremely large—just one recent Presidential directive, for example, calls for all federal employees and contractors to have biometric ID cards by the end of 2007 (a mandate covering over 19 million persons). The proposed Real ID Act will require all U.S. states to have biometric-enabled interagency and interstate identification systems and databases in place to assure documents are issued to the appropriate individual.

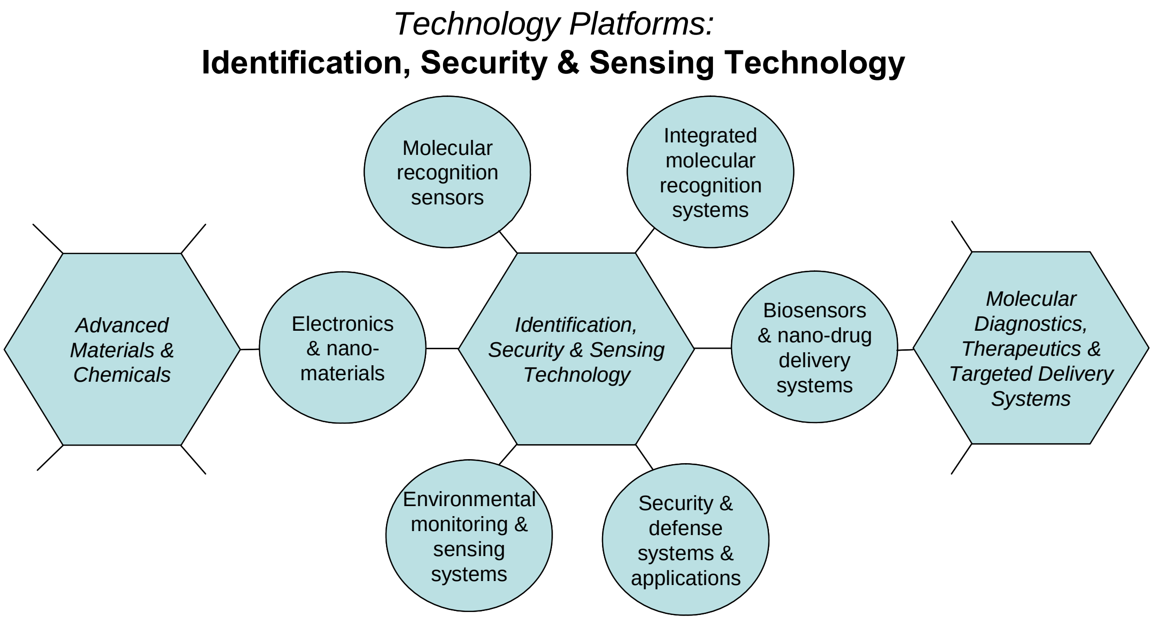
During this time of substantial market opportunity, West Virginia has developed the following significant assets that together can form the basis of a very robust platform focused on identification technology, security technology, and advanced sensing technology:

- National Biometric Security Project
- U.S. Department of Defense Biometrics Fusion Center
- Federal Bureau of Investigation Criminal Justice Information Services Division
- WVU Center for Identification Technology Research
- Forensic Science Initiative at WVU
- WVNano Initiative at WVU
- Forensic Science Center at MU

The I-79 Council is currently engaged in a Biometrics Initiative with the goal of bringing together these key assets to form a consortium of R&D and associated entities that can be greater than the sum of its parts—assuring West Virginia secures a major leadership position in the emerging identification, sensing, and associated security applications fields.

Figure ES-10 illustrates opportunity areas for technology development from the recommended identification, security, and sensing technology platform and also the cross-platform connectivity between the platform and other recommended platforms.

Figure ES-10: Identification, Security, and Sensing Technology Platform



The application of potential technologies from this platform extends beyond the identification of individual humans. The advanced sensing technologies and molecular recognition technologies likely to be developed within West Virginia will have wide-ranging applications in areas as diverse as medical diagnostics and environmental monitoring.

Molecular Diagnostics, Therapeutics, and Targeted Delivery Systems

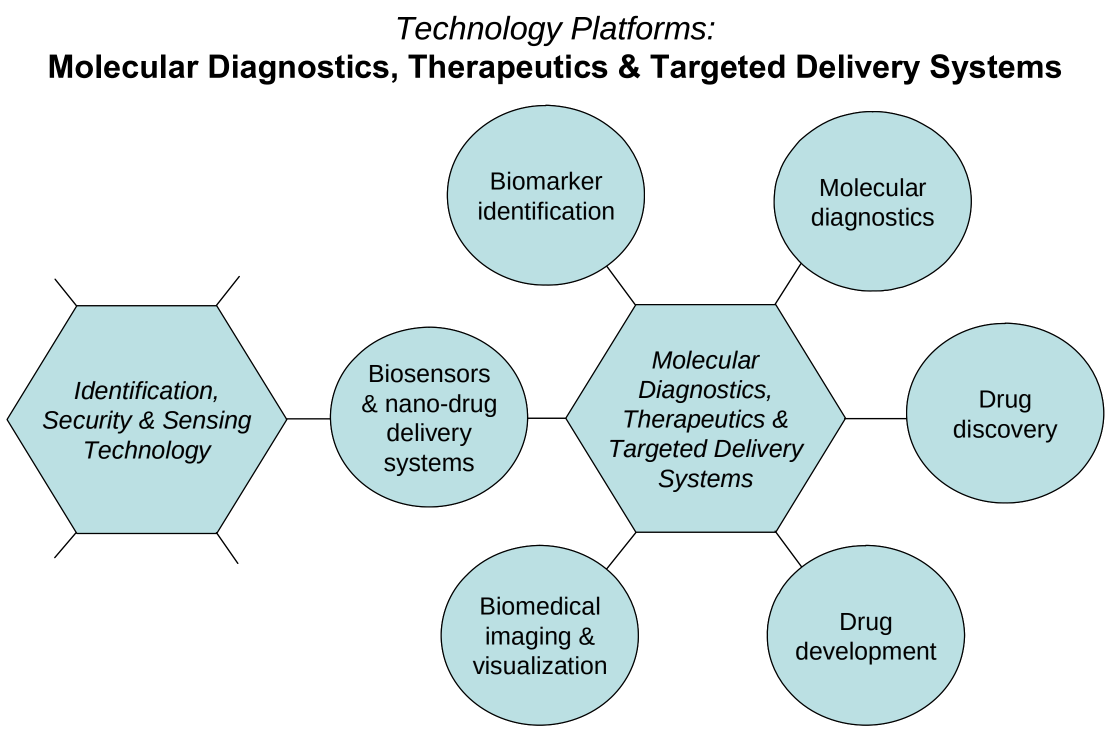
One of the key R&D growth areas within West Virginia has centered on health and life sciences. In 1997, academic life sciences R&D in West Virginia totaled $28.8 million (45 percent of total academic R&D); by 2004, this had grown substantially to $74.1 million (58 percent of total academic R&D).

Both WVU and MU have contributed to this growth, particularly within medical sciences. In terms of National Institutes of Health (NIH) awards between 2003 and 2006, MU received $19.4 million and WVU $52.2 million. Much of the R&D funded by these NIH awards has been focused in areas directly related to the identification of disease biomarkers and the potential development of diagnostics and therapeutics directed at these markers. Through the identification of specific molecular targets, in areas such as cancer and neurodegenerative diseases, discovery and development of novel therapeutics and diagnostic tools may then be pursued.

The development of a platform around molecular diagnostics, therapeutics, and targeted delivery systems in West Virginia could be supported not only by the academic R&D programs contained within WVU and MU, but also through building connections to the private pharmaceuticals industry in the state where there is considerable expertise in GMP production (especially, of course, at Mylan). Generally speaking, the development of this platform will require a long-term commitment because of the complex chain that must be built from basic science discovery, through advanced translational research, pilot production, clinical research and trials, and then into full production. Many elements of this vertically integrated chain are in place within West Virginia; but, key investments and coordinating activities will be required to produce a fully integrated system. The economic potential of successful development of marketable diagnostics, therapeutics, and drug delivery systems is, however, extremely large and warrants paying strong attention to development of this platform.

Figure ES-11 illustrates opportunity areas for technology development from the recommended molecular diagnostics, therapeutics, and targeted delivery systems technology platform and also the cross-platform connectivity between the platform and other recommended platforms.

Figure ES-11: Molecular Diagnostics, Therapeutics, and Targeted Delivery Systems Technology Platform



CONCLUSION

West Virginia is at a critical juncture in the development of its economy. The vision of a number of the state's public and private leaders has created multiple technology assets, in the form of federal and nonprofit R&D organizations, on which to build a knowledge-driven economy. Both MU and WVU are developing R&D programs that could become key drivers of the state's economy both in their respective regions and statewide. The state has growing technology industry sectors and a small cadre of technology-based start-up companies.

But, the state's technology economy is still young and must be nurtured. This will require continued investment in WVU and MU to enable them to build critical mass in key areas of research. It also will require greater industry-university collaboration, a focus on commercialization, and technical and financial support for entrepreneurs and start-up and emerging technology companies. In addition, West Virginia must grow, retain, and attract talent from world-class researchers to senior management to skilled technicians. Also, the state will need to tell both the world and its own citizens that West Virginia is changing; West Virginia is building a 21st century economy.

With the right investments, West Virginia could become a leader in the following four technology platforms identified by this analysis:

- Advanced Energy and Energy-Related Technology
- Advanced Materials and Chemicals
- Identification, Security, and Sensing Technology
- Molecular Diagnostics, Therapeutics, and Targeted Delivery Systems.

West Virginia can achieve economic development around these technology areas by building on its existing base; but, the time to act is now. West Virginia is behind many of its peer and competitor states. The state's public and private sectors need to come together and commit to taking the actions needed to compete in these areas.

West Virginia through Vision Shared and *Vision 2015* has done an excellent job of setting out a vision for the state's future and assessing the challenges it faces in achieving that vision. This analysis is the first step in preparing a blueprint that will outline specific strategies and actions to expand these technology platforms, address gaps in West Virginia's technology infrastructure, and accelerate the growth of the state's technology sectors. Completion of the Blueprint and an Implementation Plan for moving forward will help ensure that West Virginia achieves its vision of being a leader in innovation-led economic development.

Introduction

BACKGROUND

To compete in today's economy, a state must have sources of innovation and technology, a talent base of knowledge workers, capital markets that are receptive to innovative firms, and entrepreneurs who develop and apply cutting-edge technology to products and processes. New knowledge, often closely linked to cutting-edge sciences, is at the core of competitive products, processes, and business strategies.

West Virginia's Federal and Nonprofit Technology Anchors

- DoD Biometrics Fusion Center
- FBI CJIS Division
- MU Forensic Science Center
- NASA IIV&V Facility
- National Biometric Security Project
- NETL
- NIOSH
- NTTC
- Rahall Transportation Institute
- U.S. Army Corps of Engineers
- West Virginia High Technology Consortium (WVHTC) Foundation

West Virginia has historically had an economy built on energy, chemicals, and natural resources. A decade or more ago, public and private leaders began to take actions to build the infrastructure that would support innovation and knowledge-based industries, diversify the state's economy, and provide high-wage jobs for its citizens. The state's Congressional delegation succeeded in attracting federal technology projects and centers to the state. The National Technology Transfer Center (NTTC), created by Congress in 1989, was housed at Wheeling Jesuit University (WJU). In 1991, the Federal Bureau of Investigation (FBI) located its Criminal Justice Information Services (CJIS) Division in Clarksburg, West Virginia. CJIS is the central repository for criminal justice information services for the FBI. In 1993, the National Aeronautics and Space Administration (NASA) established its Independent Verification and Validation (IV&V) Facility in Fairmont, West Virginia. The facility provides IV&V services, research, and outreach for NASA.[7] The Marshall University (MU) Forensic Science Center was created by the U.S. Department of Justice in 1994, and the Nick J. Rahall Appalachian Transportation Institute was established at MU in 1998. The U.S. Department of Defense (DoD) established the Biometrics Fusion Center, which is responsible for testing and evaluating biometrics products for the military, in Clarksburg in 2000.

These operations joined existing national laboratories including the National Energy Technology Laboratory (NETL), which has been located in Morgantown since 1954, and three divisions of the National Institute for Occupational Safety and Health (NIOSH), which have been located in Morgantown since 1970. Today, NETL employs approximately 400 workers and conducts about $32 million of research and development (R&D) in West Virginia. NIOSH is the federal agency responsible for conducting research and making recommendations for the prevention of work-related injury and illness. NIOSH employs about 370 workers in Morgantown and spends $36 million annually on R&D. The U.S. Army Corps of Engineers in Huntington sponsors environmental and transportation research for the largest inland port in the United States.

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[7] A discussion of the history of the emerging technology sector in North Central West Virginia can be found in *North-Central West Virginia's Technology Industry: A Pathway Through the 21st Century*, prepared by Anderson Economic Group for the WVHTC foundation, 2006.

While these federal programs and centers were growing in West Virginia, various efforts were underway to help West Virginia companies leverage these centers by providing goods and services and by commercializing technologies being generated by these research activities. The WVHTC Foundation was created in 1990 to encourage the growth of technology companies in West Virginia. The Mid-Atlantic Technology, Research, and Innovation Center (MATRIC) was created in Charleston in 2004 to conduct research and commercialize new products and services taking advantage of the technical talent in the region. The State of West Virginia enacted the Capital Company Act designed to encourage venture capital companies to invest in West Virginia–based firms, and numerous regional and local economic development groups have worked to create a climate that will be conducive to technology firms.

These investments are bearing fruit in terms of nurturing technology-based companies in the state. Rapidly growing technology industries, with a high concentration of workers in West Virginia, include pharmaceutical and medicine manufacturing, aerospace products and parts, and oil and gas extraction. Rapidly growing industries that could become strong technology sectors are found in data processing, hosting and related services; computer systems design and related services; scientific R&D services; management, scientific and technical services; and architectural, engineering and related services. But, West Virginia continues to face challenges in growing its technology industries and transitioning its economy to one based on innovation.

Vision Shared Goals

- Increase funding for research and development
- Diversify the economy
- Address capital needs
- Increase entrepreneurship
- Restructure incentives

http://www.visionshared.com/ne/index.html

The Vision Shared Technology-Based Economic Development (TBED) Team, created to determine how to achieve the goals laid out in West Virginia's Economic Development Strategy, *West Virginia: A Vision Shared!*, is preparing a West Virginia Technology Blueprint to identify the specific strategies and actions that should be undertaken to ensure that West Virginia continues to grow its technology companies by leveraging and continuing to enhance its R&D assets and ensuring that the talent and infrastructure are in place to support technology-based development.

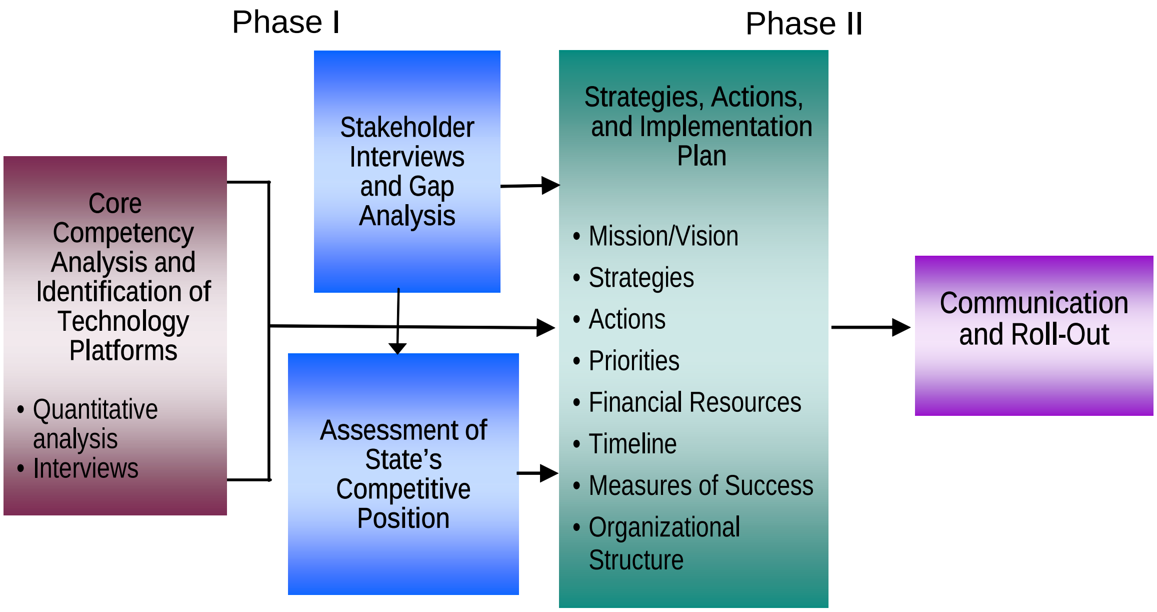
As a first step in developing the Blueprint, The Vision Shared TBED Team engaged Battelle's Technology Partnership Practice (TPP) to assist it by (1) identifying specific gaps that will need to be addressed in the Blueprint and 2) recommending specific technology platforms around which West Virginia's technology economy may be built. Battelle is the world's largest nonprofit, independent R&D organization, with 20,000 employees in more than 120 locations worldwide, including five national laboratories Battelle manages or co-manages for the U.S. Department of Energy. Battelle is a global leader in technology-based economic development, management, and commercialization and the development of partnerships among industry, government, and academia. Battelle's TPP, which includes leading analysts and practitioners in technology-based economic development, helps clients develop, implement, and evaluate technology strategies, policies, and programs.

PROJECT METHODOLOGY

The West Virginia Technology Blueprint is being developed in two phases. Phase I, the subject of this report, included review of secondary data and interviews with key public and private leaders to assess West Virginia's competitive position and to identify gaps to be addressed in the strategy. The Battelle team also conducted both a quantitative and qualitative analysis to assess West Virginia's research core competencies and identify technology platforms or areas that offer the greatest potential for West

Virginia's future economic growth (Figure 1). The results of Phase I provide the basis for proceeding with Phase II, which includes developing specific strategies and actions and an implementation plan for moving forward.

Figure 1: Development of West Virginia's Technology Blueprint



West Virginia's Technology Economy

WHY FOCUS ON TECHNOLOGY?

The development and application of technology is driving the nation's economic growth. Economists calculate that approximately 50 percent of U.S. gross domestic product is attributed to increases in innovation.[8] Those states and regions that will succeed in building robust, competitive economies will be those that have well-developed technology industry clusters. A study by the Milken Institute, a private nonprofit research organization, examined 315 regions in the United States between 1975 and 1998 and found that 65 percent of the economic success of a region is attributed to the growth and presence of high-technology industries.[9]

Technology is and will continue to be essential to the growth and success of the modern economy. The automation and customization of manufacturing processes are a precondition for efficiency and profitability within manufacturing enterprises around the globe. Computers and communication technologies have become ubiquitous throughout the industrial and business world. The biological and life sciences have become leading research fields.

Technology is critical not only for West Virginia's new, emerging industries, but for its established industries as well. Many "mature" industries meet the definition of being "high-technology." The most well-grounded approach to defining technology-related industries is that adopted by the U.S. Bureau of Labor Statistics (BLS), which considers the share of the workforce in scientific, engineering, and technology-related occupations. Only those industries with at least twice the average for all industries are considered high-technology. Many well-established mature industries are mainstays of the advanced technology industry base.

"Mature" high-technology industries

- Plastics
- Engines and turbines
- Motor vehicles
- Electrical instruments
- Electric distribution equipment
- Measuring and control devices
- Industrial machinery
- Engineering services
- Construction machinery
- Industrial chemicals
- Petroleum refining
- Soaps, cleaners, and toilet goods

Technology industries offer high-paying, quality jobs across a range of occupations. Technology industries offer employment that requires a variety of skills and education, from Ph.D. researchers to technicians and production workers. The average salary for a worker in a high-technology company in West Virginia in 2005 was $55,490, compared with $30,545 for the average private sector employee. Increasing the number of such jobs would allow more of West Virginia's young people to stay in the state after graduating from the state's higher education institutions. These technology jobs also create additional jobs throughout the economy. Battelle estimates, for example, that each bioscience job in the United States results in 5.7 additional jobs.[10]

The state's base of technology companies must be expanded to complete the transition of West Virginia's economy from one based on coal, traditional manufacturing, and low-cost service

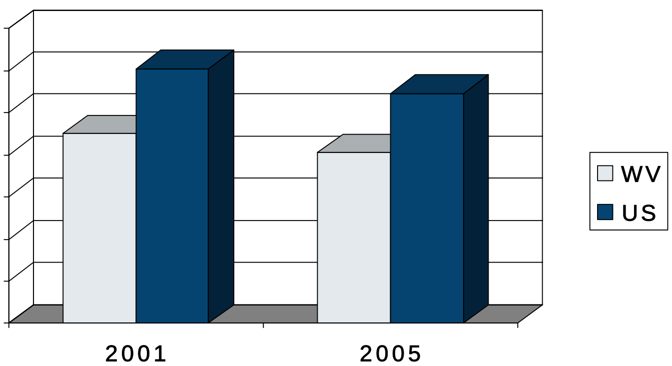
[8] Council on Competitiveness, *National Innovation Initiative*, 2005.
[9] Milken Institute, *America's High Tech Economy*, 1999.
[10] Battelle and SSTI, *Growing the National's Bioscience Sector: State Bioscience Initiatives 2006*, 2006.

operations to one based on technology industries such as advanced manufacturing, advanced materials, new sources of energy, and the biosciences. West Virginia is in an economic race to the future, where the keys to success will depend upon knowledge, innovation, and intellectual capital. The economic future of West Virginia will depend on its ability to make technology a key driver of its economy.

West Virginia's Technology Industry

An examination of West Virginia's technology industry base shows that West Virginia has yet to reach critical mass. In 2005, high tech industries accounted for 8.1 percent of West Virginia's private sector employment[11] compared to 10.9 percent nationally (Figure 2). Both nationally and in West Virginia high tech employment declined between 2001 and 2005. However the decline in West Virginia of 8.5 percent was slightly lower than the 8.7 percent decline experienced nationally.

Figure 2: Percent of Total Employment in High-Tech Industries, West Virginia and United States, 2001 and 2005



Source: BLS and Battelle calculations.

High-tech sectors contributed approximately 14 percent of West Virginia's gross state product (GSP) from 1997 to 2004.[12] West Virginia is 26 percent less concentrated in high-tech employment than the nation, with a location quotient (LQ) of 0.74. [13] On a regional basis, however, the I-79 corridor in North Central West Virginia (Monongalia, Marion, Harrison, and Lewis Counties) has an LQ of 1.04, meaning that it has a slightly higher concentration of high-tech employment than the nation. The region is experiencing rapid growth of its high-technology sector, resulting in its LQ increasing from 0.74 to 1.04

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[11] High-technology industries include those sectors identified by the BLS as having a significant core of occupations highly related to technology. An industry is considered high-tech if employment in technology-oriented occupations (scientists, engineers, and technicians) account for a share of total employment that is at least twice the 4.9 percent average for all U.S. industries. BLS further breaks down the industries into three levels. Level I includes industries in which technology-orientated occupations account for a share at least five times the average. Level II includes industries with 3.0 to 4.9 times the average, and Level III includes 20 industries with a share 2.0 to 2.9 times the average.

[12] Regional Research Institute, West Virginia University, *Resource Inventory and Assessment*, December 2006.

[13] LQs are a standard measure of the concentration of a particular industry in a region relative to the nation. The LQ is the share of total employment in the particular industry divided by the share of total industry employment in the nation. An LQ greater than 1.0 for a particular industry indicates that the region is relatively concentrated, whereas an LQ of less than 1.0 signifies a relative underrepresentation. An LQ greater than 1.2 denotes employment concentration significantly above the national average and is referred to as a "specialization."

between 2001 and 2005. This indicates that high-tech employment in the region has been growing much more rapidly than in the nation. While West Virginia does not have a specialization in the overall high-tech sector, the state does have specializations (defined as LQs of 1.2 or greater) in technology industry sectors that are growing. These include oil and gas extraction, in which employment grew almost 20 percent between 2001 and 2005, and pharmaceutical and medicine manufacturing, which grew 67 percent in employment during the same time period. It should be noted, however, that the pharmaceutical and medicine manufacturing sector includes only five establishments;[14] thus, this growth has been concentrated in a small number of companies (Table 1).

Table 1: Selected West Virginia High-Tech Sector Employment, Establishments, and Wages, 2001–2005

High Technology Sectors	Estab. Q1 2005	Estab. % Chg. '01–'05	Empl. Q1 2005	Empl. % Chg. '01–'05	LQ, Q1 2005	Avg. Annual Wage, Q1 2005
Total West Virginia High-Tech Sectors	**2,883**	**-4.3**	**45,329**	**-8.5**	**0.74**	**$74,492**
High-Tech Sectors in which West Virginia has a concentration greater than the national average						
Pipeline Transportation of Natural Gas	83	-13.4	1,451	-17.2	**11.21**	$85,480
Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments Manufacturing	18	63.6	3,018	-28.4	**5.61**	$65,566
Basic Chemical Manufacturing	40	0.0	4,115	-37.7	**5.61**	$77,337
Oil and Gas Extraction	217	-7.3	1,980	19.7	**3.12**	$117,225
Electric Power Generation, Transmission, and Distribution	123	2.5	4,609	-9.1	**2.29**	$79,240
Petroleum and Coal Products Manufacturing	34	47.8	1,107	-1.0	**1.95**	$82,588
Pharmaceutical and Medicine Manufacturing	5	18.5	2,370	67.3	**1.63**	$82,820
Wired Telecomm Centers	174	-31.0	2,988	-27.6	1.17	$69,452
Aerospace Products and Parts Mfg.	14	-6.7	2,485	19.5	1.09	$72,712
Emerging High Growth Sectors						
Data Processing, Hosting and Related Services	55	34.1	745	24.4	0.56	$30,893
Computer Systems Design and Related Services	341	-4.7	2,269	23.4	0.38	$53,216
Management of Companies and Enterprises	191	11.0	3,541	27.6	0.40	$53,775
Management, Scientific and Technical Consulting	445	18.4	2,421	22.8	0.56	$48,580
Scientific R&D Services	73	25.9	1,371	16.2	0.47	$49,927
Architectural Engineering & Related Services	569	-0.7	4,882	10.7	0.74	$42,903

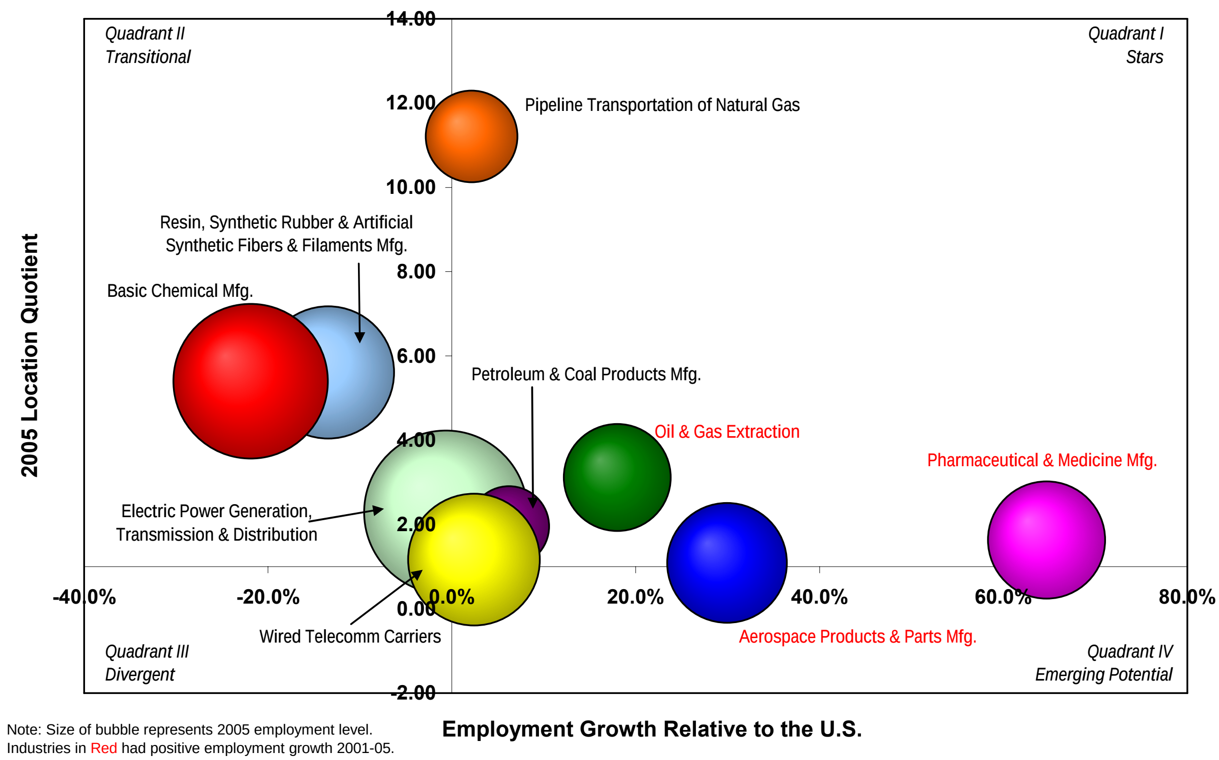
Source: Battelle calculations based on BLS, Quarterly Census of Employment and Wages (QCEW) Program data. State specializations are highlighted in red.

[14] An establishment is a place of business. If a corporation has more than one location in the state, each location would be counted as one establishment.

West Virginia is very specialized in pipeline transportation of natural gas; resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing; and basic chemical manufacturing; but, all of these industries experienced employment declines between 2001 and 2005. Aerospace products and parts manufacturing, while not yet a specialization, is approaching one. Employment in this sector grew 20 percent between 2001 and 2005.

Figure 3 compares the performance of West Virginia's high tech sectors with that of the nation between 2001 and 2005. In Figure 3, West Virginia's high-tech sectors are classified according to employment size, comparative growth rate, and relative concentration. The size of each bubble corresponds to the amount of employment in that industry. Vibrant, mature sectors, those with a greater concentration and faster growth rate than the nation are found in the upper right-hand quadrant. Pharmaceutical and medicine manufacturing, aerospace products and parts manufacturing, oil and gas extraction, petroleum and coal products manufacturing and pipeline transportation of natural gas are all in this quadrant. Basic chemical manufacturing, and resin, synthetic rubber, and artificial synthetic fibers and filament manufacturing are in the transitional quadrant, meaning that West Virginia has a specialization in these industries, but they are not keeping pace with the employment growth of those sectors nationally.

Figure 3: Performance of West Virginia's High-Tech Industries Relative to the Nation, 2001–2005

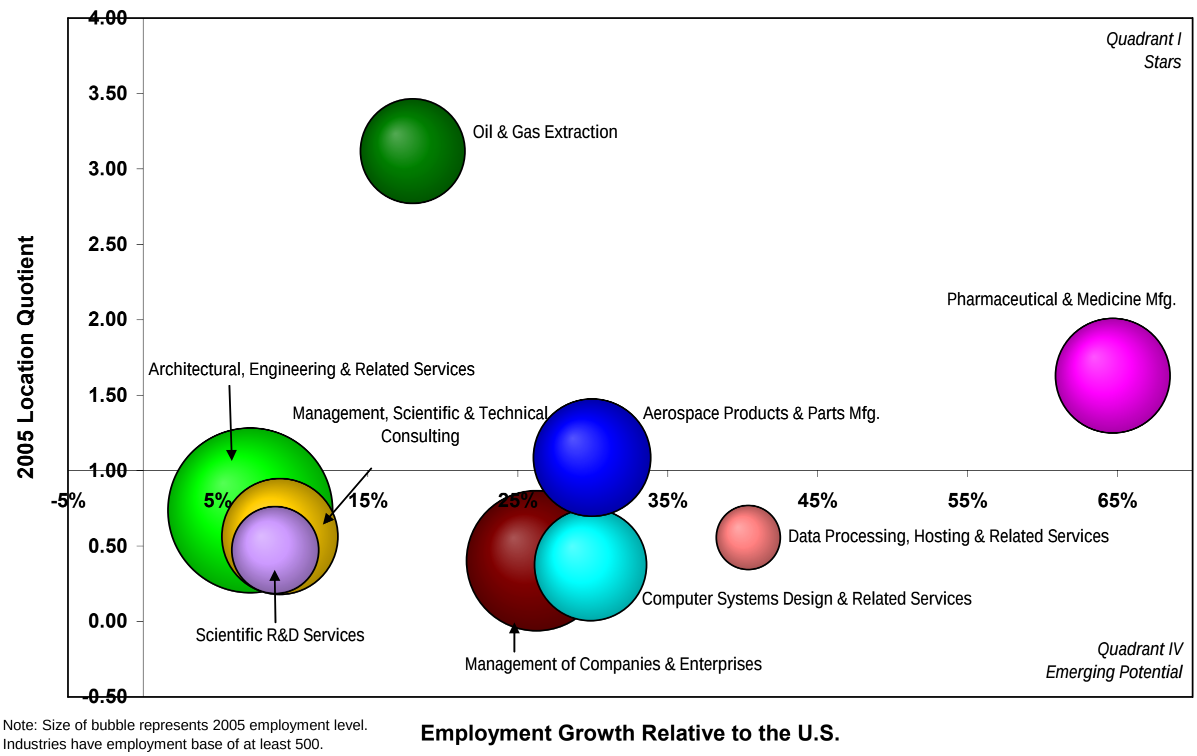


Source: Battelle calculations based on BLS QCEW program data from the Minnesota IMPLAN Group.

West Virginia also has a number of emerging potential high-tech industries. West Virginia does not have a concentration in these industries, but they are growing in the state at a faster pace than in the nation. Data processing, hosting and related services; computer systems design and related services; management of companies and enterprises; management, scientific and technical consulting; architectural, engineering and related services all experienced at least 10 percent growth in employment between 2001 and 2005;

and each grew faster than their respective industry at the national level. Most of these sectors have a significant number of establishments, suggesting that they are composed of smaller companies; most experienced an increase in the number of establishments between 2001 and 2005, suggesting that these are areas of entrepreneurial activity in West Virginia (Figure 4).

Figure 4: West Virginia's Emerging Potential High-Tech Industries' Degree of Specialization and Employment Growth, 2001–2005



Source: Battelle calculations based on BLS, QCEW program data from the Minnesota IMPLAN Group.

The data indicate that West Virginia has existing and emerging technology industry clusters. But, how well positioned is the state to nurture and grow these clusters and to compete not only on a regional and national basis but on a global basis as well? The next section outlines the key factors needed to support the development of a technology economy, assesses West Virginia's strengths and weaknesses in regards to each, and identifies opportunities to be leveraged and gaps to be addressed to build West Virginia's tech-based economy.

Building a Technology-Based Economy

West Virginia through the Vision Shared process committed to developing the state's innovation- and knowledge-based economy and proposed that technology would be "a definite linchpin for successful diversification of the State's economy in the long-term."[15] But, how does West Virginia compete in the key factors necessary to grow such an economy? To answer this question, Battelle reviewed secondary data and conducted extensive interviews with entrepreneurs; industry chief executive officers (CEOs); industry organization representatives; leadership within higher education, workforce development programs, and economic development organizations; state government officials; federal laboratory representatives; service providers; and investors. Interviews were conducted on-site in Charleston, Fairmont, Huntington, Morgantown, and Wheeling and by phone. The conclusions presented in this section are based on this collective input as well as Battelle's knowledge of TBED efforts underway across the country.

KEY SUCCESS FACTORS

Silicon Valley, Route 128, the Baltimore-Washington Corridor, and Research Triangle Park are generally regarded as the nation's premier technology-driven centers of commerce. An examination of the factors that have enabled these regions to succeed in growing their technology base demonstrates that they share the following characteristics:

- **Engaged universities with active leadership and strong ties to industry.** Technology-driven economies have outstanding research institutions committed to building and sustaining technology-intensive industrial sectors. Successful states and regions depend on institutional excellence in pertinent areas of science and engineering research to drive the economy. They also recognize that achieving the requisite level of quality and critical mass within its research base requires public investment. However, academic stature is not sufficient by itself to drive a technology-based economy. Strong technology communities nearly always feature top institutional leadership that is fully committed to engaging with industry and institutional cultures that are comfortable participating in the conversion of intellectual capital into economic activity. It is important to note, however, that programmatic incentives are often required to ensure that these goals of public purpose lead to institutional action.
- **Intensive networking across sectors and with industry.** Mechanisms that facilitate intensive networking within and between industry sectors cultivate a proactive environment. The most successful technology regions facilitate extensive and intensive

Key Success Factors

- Engaged universities with active leadership and strong ties to industry
- Intensive networking across sectors and with industry
- Available risk capital covering all stages of the business cycle
- Discretionary federal or other R&D funding support
- Workforce and talent pool upon which to sustain efforts
- Stable and supportive business environment
- Patience and a long-term perspective

[15] http://www.visionshared.com/ne/it.html.

networking both across the academic-industrial boundary and between companies in allied sectors or in a supply-chain relationship. In a very few leading communities like Silicon Valley, this networking has occurred naturally, with formal organizations like Joint Venture-Silicon Valley coming only later. However, in the vast majority of regions attempting to build technology sectors, formal networking organizations are built from the ground up; otherwise, the desired degree, scale, and intensity of networking will not occur.

- **Available risk capital covering all stages of the business cycle.** Access to early-stage risk capital is a critical factor in building a technology-driven economy. One characteristic shared by leading technology regions is that they are home to a venture capital community committed to early-stage local investment. These regions also have networks of successful entrepreneurs who act as angel investors, willing to invest in very early-stage start-up companies. Building a base of angel investors and venture capital funds able and willing to invest in emerging companies is a challenge for many regions. It is also critical to have financing available for each stage of development from early-stage, proof-of-concept and prototype development to venture financing. Leading technology regions typically have access to commercialization funding, pre-seed and seed funding, and venture financing.
- **Discretionary federal or other R&D funding support.** To build generic R&D assets into an effective attractor of technology investment requires leveraging of substantial, ongoing, external, discretionary funding. While the first technology centers in California and Massachusetts were able to leverage a heritage of heavy defense spending, and while Baltimore and Washington leveraged growing Congressional support of federal laboratories owned by the National Institutes of Health (NIH), the National Institute of Standards and Technology (NIST), and the U.S. Food and Drug Administration, most other regions must use state funding as a lever to attract strategic external investments.
- **Workforce and talent pool upon which to sustain efforts.** A supply of qualified, technology-trained workers is critical to the development and sustainability of a technology-based/advanced manufacturing economy. Any knowledge-based industry requires a supply of qualified, trained workers at all levels. Successful regions maintain an adequate supply of not only doctoral-level researchers, but also technicians with 2-year degrees and managerial talent ranging from entrepreneurs to mid- and senior-level executives comfortable with high-technology settings. Regions without a deep, natural pool of talent use a variety of tools, including formal university curricula, marketing programs aimed at worker retention, and peer support for entrepreneurs.
- **Stable and supportive business environment.** Advanced manufacturing/technology-based economies thrive in a stable and supportive environment in which tax and incentive policies are used to spur growth. Advanced manufacturing and technology-intensive companies need a tax environment that values their contribution to regional economic vitality and recognizes their specific requirements. Policies that recognize the long development cycle in technology, particularly in the life sciences, can help firms maintain a sound capital structure and ensure a level playing field with respect to old economy industries.
- **Patience and a long-term perspective.** One final lesson from every successful technology community is that success takes time. Silicon Valley and Route 128 trace their origins in electronics to the 1950s and in the life sciences to the 1970s. Research Triangle Park represents a 50-year strategy that has only recently found its footing in the biosciences and is still working to develop full

capability in the entrepreneurial sector. Success requires a long-term perspective and patient commitment.

ASSESSING WEST VIRGINIA'S COMPETITIVE POSITION

Developing an effective technology strategy requires an understanding of how a state compares on key factors. Battelle reviewed data for West Virginia and conducted numerous interviews to gain an understanding of West Virginia's R&D base, university-industry linkages, workforce, entrepreneurial climate, and capital markets. On selected measures, Battelle compares West Virginia to six benchmark states—Arkansas, Idaho, Kentucky, Maine, Oklahoma, and Tennessee. These states were selected because they shared similarities to West Virginia in terms of size and makeup of their industrial base or because they are actively implementing policies and programs to grow their technology sectors. The findings from this analysis are discussed below.

R&D Base

Why It's Important

To compete in today's' economy, a state must have sources of innovation and technology. A strong presence of research institutions, including universities, academic medical centers, national laboratories, and nonprofit research institutions, with recognized areas of research excellence, is critical for regions and states seeking to grow technology-based economies. First, the research conducted at these institutions generates new knowledge and technology, forming the basis for creating new firms and introducing new products in the marketplace. Second, these organizations both attract and produce highly trained personnel who provide the skilled workforce needed by technologically advanced companies. Third, the presence of such a workforce, in turn, attracts technology companies to locate near centers of excellence.

Where West Virginia Stands

West Virginia has a growing R&D base driven by its federally funded R&D centers that is competitive with many of the benchmarks; but, the state trails the benchmark set in terms of academic and industrial R&D. West Virginia ranked fifth among the benchmarks in terms of total R&D expenditures (expenditures from academic institutions, industry, federal organizations, federally funded research and development centers, and nonprofit centers), which totaled $538 million in fiscal year (FY) 2003. West Virginia ranked third, however, behind only Idaho and Tennessee, when taking into account the size of each state's economy as measured by dollars of R&D per dollars of GSP. R&D accounted for 1.15 percent of West Virginia's GSP (Table 2).

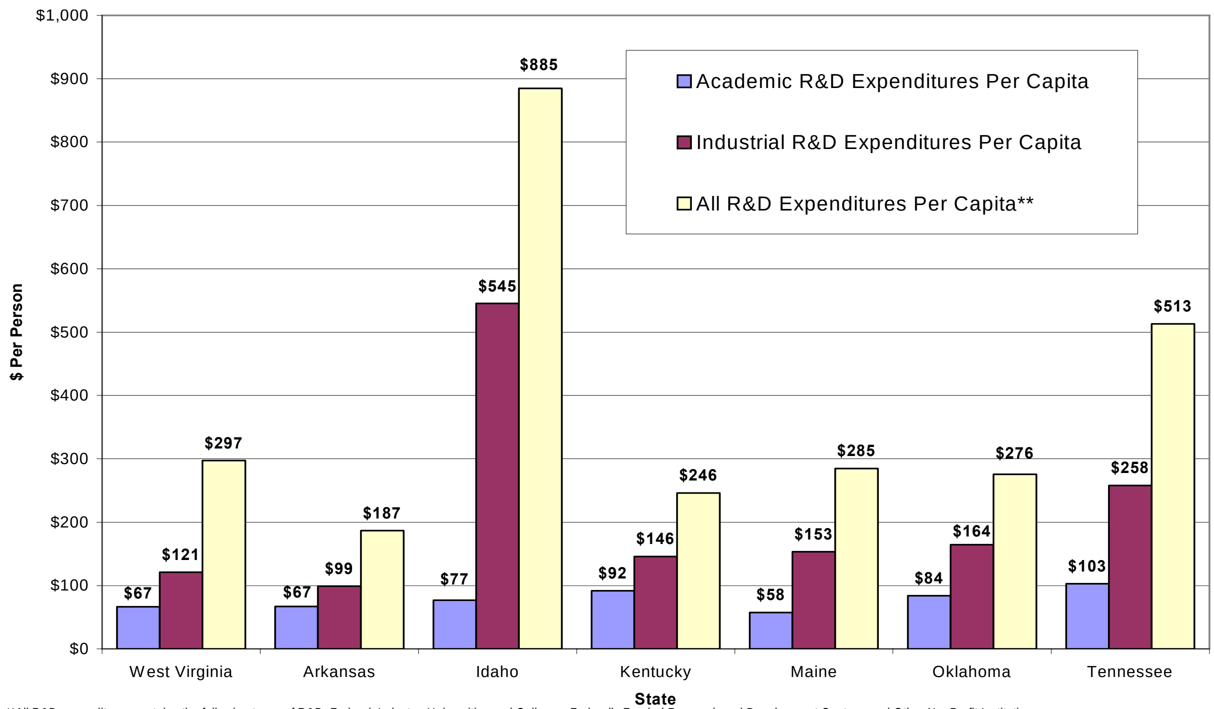
On a per capita basis, West Virginia ranked behind only Tennessee and Idaho among the benchmark states, at $297 in per capita R&D. Idaho and Tennessee rank highly in terms of per capita R&D spending because each is home to a large federal laboratory, the Idaho National Laboratory and Oak Ridge National Laboratory, respectively. Similarly, West Virginia benefits from the presence of federally funded R&D projects and centers. West Virginia ranked fifth in terms of academic R&D expenditures behind Idaho, Kentucky, Oklahoma, and Tennessee. Only Arkansas ranked lower than West Virginia in terms of per capita industrial R&D spending (Figure 5).

Table 2: R&D Expenditures and GSPs for West Virginia and Benchmark States, 2003 ($ millions)

State	All R&D Expenditures	GSP	R&D Intensity (R&D/GSP)	Rank of R&D Intensity
West Virginia	538	46,726	1.15%	38
Arkansas	509	74,540	0.68%	47
Idaho	1,209	40,358	3.00%	12
Kentucky	1,014	128,315	0.79%	46
Maine	372	40,829	0.91%	45
Oklahoma	968	101,168	0.96%	42
Tennessee	2,998	203,071	1.48%	33

Source: National Science Foundation (NSF) R&D Expenditures and U.S. Bureau of Economic Analysis.

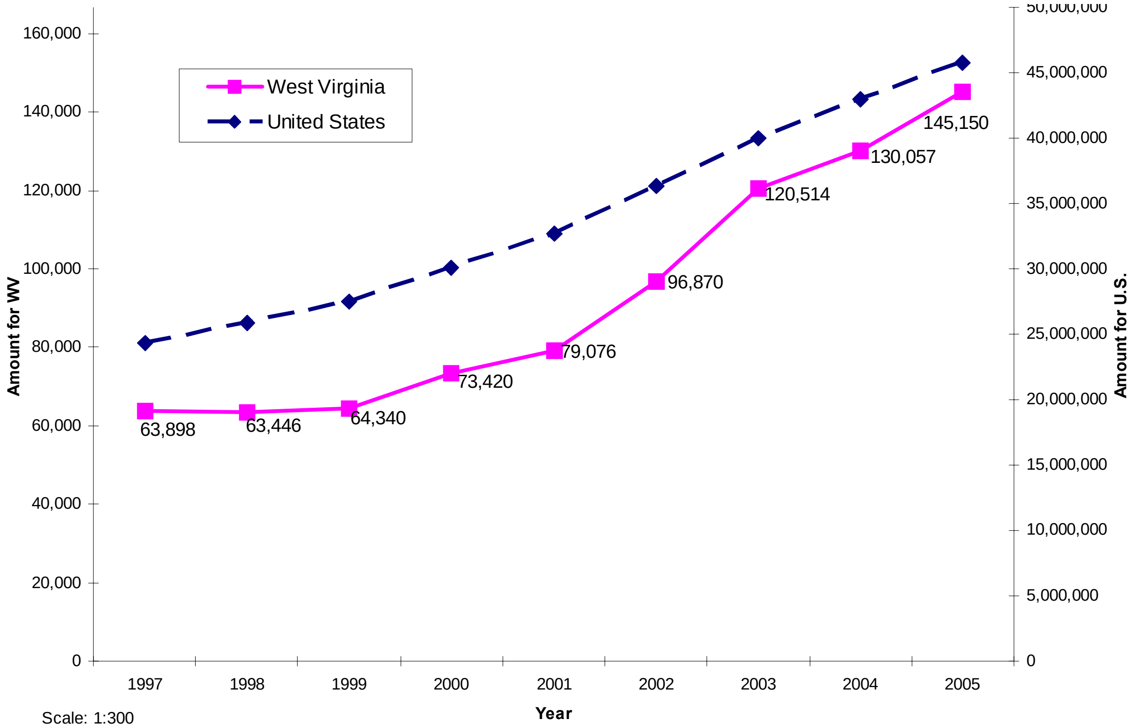
Figure 5: Per Capita R&D Expenditures by Type for West Virginia and Benchmark States, 2003



**All R&D expenditures contains the following types of R&D: Federal, Industry, Universities and Colleges, Federally Funded Research and Development Centers, and Other NonProfit Institutions
Sources: NSF Expenditures, and U.S. Census

West Virginia's universities have experienced significant growth in their R&D activities, outpacing growth in academic R&D nationally. Total academic expenditures in West Virginia were approximately $145 million in 2005 and have been growing at a pace that exceeds that of the nation, increasing by 85 percent between 2001 and 2005 as compared with approximately 40 percent nationally (Figure 6).

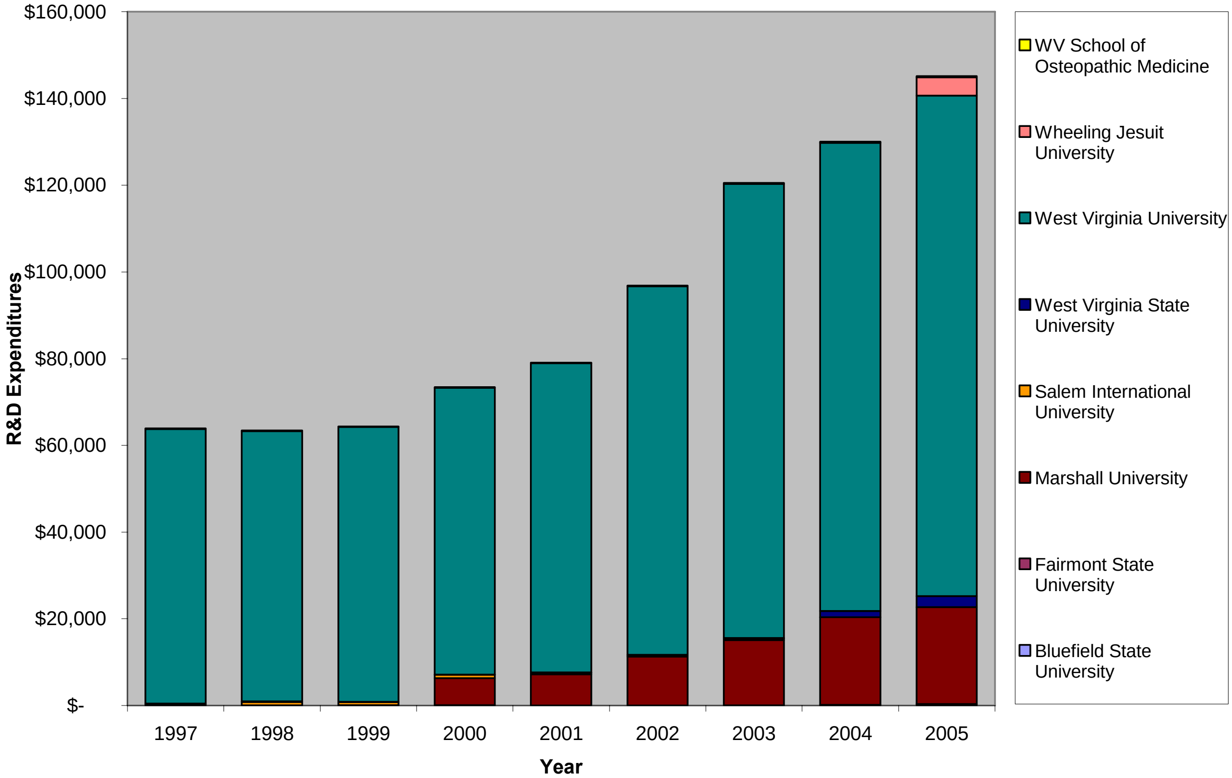
Figure 6: Academic R&D Expenditures for West Virginia and United States, 1997–2005 ($ in thousands)



Source: NSF Academic R&D Expenditures, 2005; Battelle calculations.

The overwhelming majority of academic R&D expenditures in West Virginia is contributed by two schools—West Virginia University (WVU) and MU—and both continue to invest in growing their respective R&D enterprises (Figure 7). Of note, MU's level of academic expenditure has increased dramatically in recent years, from less than $1 million in 1999 to upward of $20 million in 2004. And, both WVU and MU are continuing to invest in new infrastructure and personnel. MU just completed construction of the $39 million Edwards Comprehensive Cancer Center, which includes an entire floor dedicated to translational research. In addition, MU's 144,000 square-foot Robert C. Byrd Biotechnology Science Center, which opened in August 2006, contains a new, fully equipped Molecular and Biological Imaging Center and a state-of-the-art Genomics Facility. A new medical research building to house the Blanchette Rockefeller Neurosciences Institute (BRNI) is under construction at WVU, with completion expected in Spring 2008. Both WJU and West Virginia State University increased their R&D funding in 2005 as well.

Figure 7: Academic R&D Expenditures by West Virginia School, 1997–2005 ($ in thousands)



Source: NSF Academic R&D Expenditures, 2005; Battelle calculations.

University-Industry Linkages

Why They're Important

The presence of universities, in and of itself, does not necessarily lead to economic development; rather, it is the alignment of the research interests of faculty and industry and their collaboration that enables industry to move new discoveries into the marketplace. Key shifts are taking place in how R&D is conducted, demanding new types of strategic alliances to gain competitive advantages from research capabilities. With the decline of major corporate research laboratories, such as the former Union Carbide R&D laboratory in Charleston, and a focus by corporations on diversifying their sources of innovation, there is a rising need for strategic alliances across universities and industry to fill the demand for innovation. In the absence of major corporate research laboratories to move technology forward, universities are being pressured to further develop their research discoveries to make them commercially viable.

States and regions promoting a broader culture of collaboration across their university and industry sectors will be big winners in this changing paradigm, not only supporting local industries, but also attracting major outside investment. It will also become important for states to ensure that sources of research expertise and capacity exist to support the range of research needs across their specific economic clusters.

Where West Virginia Stands

West Virginia's research institutions do not appear to be strongly linked to industry. West Virginia's universities and colleges received only $4 million out of a total of $130 million (about 3 percent) in R&D funding from industry in FY 2004, although the $4 million was a significant jump from the $2 million received from industry in FY 2003 (Table 3). This is significantly below the national average which, in 2004, was approximately 5 percent. Largely, this lack of industry involvement results from the industrial makeup of the state and the absence of a mature, established technology sector. But, it also results from the state's tendency to be home to companies headquartered elsewhere and the tendency of its home grown technology firms to be small. Such start-up and emerging firms usually lack the resources to partner with academic institutions unless a subsidy is provided to allow them to do so. It may also reflect the fact that West Virginia's research programs are still developing and have yet to attract significant industry funding from outside the state.

Table 3: West Virginia's Industrial and Academic R&D Expenditures ($ in millions)

	Industrial R&D Expenditures		Academic R&D Expenditures	
Finance Type	**2003**		**2003**	**2004**
Federal	21		74	79.5
State and Local			3	5
Industry	198		2	4
Institution			39	39
All Other Types			3	2.5
Total	**219**		**121**	**130**

Both MU and WVU, however, have made recent commitments to promoting commercialization and supporting start-up and emerging companies. MU recently created a Technology Transfer Office (TTO) whose mission is to "make the unique products and services generated by our faculty, staff, and students available to the public for commercialization."[16] The MU TTO is working with local economic development organizations to provide support to its start-up companies. WVU created its Office of Technology Transfer in 1999 and since then has been focusing on both growing WVU as a research institution and linking it to economic development. WVU has a business incubator and is in the process of developing a research park, with work about to begin on an initial 66,000-square-foot building that will include wet-lab–equipped incubator space and multitenant space.

Both MU and WVU are spinning off new companies based on discoveries made in the universities. Examples of such companies include the following:

- Choosy Kids, LLC, a child-wellness products and service company located in the WVU incubator
- EyeMarker Systems, an emerging company located in the WVU incubator that is seeking to commercialize an innovative ocular screening technology
- InSenSys, a spin-off of MU's Rahall Transportation Institute, which provides a railway inspection system
- Medical Information Systems Technology (MIST) is a Huntington based start-up that is commercializing technology developed at MU that improves treatment of preclampsia in pregnant women
- Parentage Testing Services, a spin-out of the MU Forensic Science Center

[16] http://www.marshall.edu/ott/.

- Protea Biosciences, Inc., a spin-out of WVU, which is developing products to improve protein sample preparation for downstream analysis, especially by mass spectroscopy
- Vandalia Research, Inc., an MU spin-out, which is commercializing novel biotechnology instrumentation and advanced biotechnology manufacturing techniques
- vIDentity Systems, Inc., a tenant in the WVU incubator, which develops secure verification services through the use of biometrics.

Technically Skilled and Well-Educated Workforce

Why It's Important

It is becoming generally accepted that human capital will be the key differentiator between winning regions and losing ones. Without skilled people, technology innovation cannot occur and advanced technologies cannot be deployed. A supply of qualified, technology-trained workers is critical to developing and sustaining a technology-based economy. Any knowledge-based industry requires a supply of qualified, trained workers at all levels, including doctoral-level researchers, technicians with 2-year degrees, and managerial talent ranging from entrepreneurs to mid- and senior-level executives comfortable with high-technology settings.

Where West Virginia Stands

West Virginia has a highly productive workforce. Interviewees across the board stated that one of the greatest strengths of West Virginia is its workforce, which was described as hard-working, honest, innovative, and talented. The workforce of the Toyota plant in Buffalo, West Virginia, which has consistently ranked as the most productive auto engine plant in the nation, was cited as an example of this advantage. *The Harbour Report*, which is issued annually, reported as follows:

> *Toyota's four-cylinder line in Buffalo, WV, was again the report's most productive engine operation for the fifth consecutive year at 1.82 hours per engine (HPE). It's only the third time* The Harbour Report *has had an engine plant with an HPE measure below 2, and both times it was Toyota West Virginia.*[17]

Employers interviewed also indicated that they are pleased with the quality of the graduates of West Virginia's colleges and universities, indicating that they are usually able to hire entry-level engineers and other professional workers locally. Indeed, there are more quality graduates than there are employment opportunities for them. West Virginia's colleges and universities awarded 95 doctoral degrees, 458 master's degrees, and 1,862 bachelor's degrees in the biological sciences in 2005. Another 29 Ph.D.s, 248 master's degrees, and 602 bachelor's degrees were awarded in the physical sciences, including engineering (Table 4).

[17] Harbour Consulting. *2006 Harbour Report, North America Press Release*, June 2006.

Table 4: Degrees Awarded by West Virginia's Educational Institutions by Field, 2005

Field	Award Type					Share of Total
	Associate's	Bachelor's	Master's	Ph.D.s	Professional	
Biological Sciences	1,287	1,682	458	95	307	23%
Physical Sciences	350	602	248	29		7%
Other	2,126	7,418	2,029	89	142	70%
Total for West Virginia	**3,763**	**9,702**	**2,735**	**213**	**449**	

Source: National Center for Education Statistics, 2005.

Overall, however, the population is not highly educated, making it difficult to find highly skilled technical people and to attract technology companies that might consider a location in West Virginia. Only 16.9 percent of West Virginians 25 years or older have completed a bachelor's degree, compared with 27 percent nationally. And while West Virginia has increased the percentage of 18- to 24-year-olds with a high school credential from 83 percent to 87 percent between 1992 and 2006, this is still below the high school completion rate of 94 percent in top performing states. A report that evaluates states on their performance in higher education summarized West Virginia's performance as follows:

> *West Virginia's underperformance in educating its young population could limit the state's access to a competitive workforce and weaken the economy over time. Compared with other states, relatively few 9th graders graduate from high school in four years and enroll in college by age 19. In addition, West Virginia trails other states in providing college-level training opportunities for working-age adults.*[18]

As West Virginia grows its technology industries, programs will be needed—particularly at the technician and associate's level—to provide residents with the skills to fill technical-level jobs. Resources for doing this are presently limited in West Virginia.

Young, single, and well-educated people, a potential source of talent, are out-migrating from West Virginia for want of good employment opportunities. Between 1995 and 2000, West Virginia experienced a net out-migration of 4,691 individuals aged 25 to 39 who were single and held at least a bachelor's degree.[19] West Virginia's out-migration of such young, educated people exceeded that of all the benchmark states. Of the benchmarks, only Idaho and Tennessee experienced an in-migration of young, single, well-educated people. It is clear that West Virginia is producing educated individuals who could serve as a talent pool as the state's technology sector continues to expand.

Entrepreneurial Climate and Support for New Enterprise Development

Why It's Important

Innovation, in and of itself, will not necessarily translate into economic activity. Rather, it is the application of a technology and its introduction into the marketplace that result in economic growth. A number of studies and reports in recent years point to the importance of entrepreneurship in changing regional economies. Studies prepared initially by David Birch, validated by the Office of Advocacy of the U.S. Small Business Administration (SBA), and further refined by studies commissioned in recent years

[18] The National Center for Public Policy and Higher Education, *Measuring Up 2006: The State Report Card on Higher Education*, 2006.
[19] http://www.census.gov/population/www/cen2000/migration.html.

by the Kauffman Foundation and others clearly indicate that technology, innovation, and entrepreneurship drive economic growth. "The large portion of entrepreneurial firms and the significant number of jobs created by newer, small firms in the United States are a strong indication that the entrepreneurial sector with its flexibility and capacity to adapt quickly is poised to become an even more important protagonist in the future economic growth of the country."[20]

A 2005 report prepared for the SBA's Office of Advocacy comparing regions with strong and weak entrepreneurial activity found that "the most entrepreneurial regions had better local economies from 1990 to 2001 compared to the least entrepreneurial. They had 125 percent higher employment growth, 58 percent higher wage growth and 109 percent higher productivity. This general finding held individually for large, medium and small-sized regions but was most pronounced for large regions."[21]

Supporting entrepreneurs and the growth of entrepreneurial companies must therefore continue to be a critical component of any state's or region's strategy to accelerate the growth of its technology-based economy. The National Governors Association puts forth this definition of entrepreneurship and entrepreneurs:

> Entrepreneurship is the ability to amass the necessary resources to capitalize on new business opportunities; and an entrepreneur is one who combines smart business practices with innovation, without regard for resources under his or her control.[22]

The resources that they need include management talent, technology, capital, professional expertise, and a host of other services. They often need assistance in determining economic feasibility and identifying markets and distribution channels. They may also need access to specialized equipment and laboratories and to expertise to solve technical issues that arise during product development. They must be able to recruit key personnel and have access to small amounts of pre-seed capital.

Entrepreneurs

- Commercialize innovative products and services that improve quality of life
- Create dynamic and flexible new industries and firms to replace those that are no longer viable in a rapidly changing global economy
- Provide most new employment opportunities
- Create wealth that is reinvested in new enterprises and, through demonstrated philanthropic activity, in communities

Where West Virginia Stands

West Virginia's entrepreneurial support infrastructure is expanding. Statewide and regional programs are assisting entrepreneurs and emerging companies. WVHTC Foundation's INNOVA program is a commercialization assistance program launched in 2002. INNOVA provides start-up and business support services, makes seed and early-stage investments, and provides entrepreneurial training. INNOVA, with funding from the Kauffman Foundation, offers the FastTrac® program, a practical hands-on business development program developed by the Kauffman Foundation. Fast Trac® helps entrepreneurs obtain the skills they need while working to launch their business venture. The 10-week Fast Trac® program has been offered at various locations around the state.

[20] *Global Entrepreneurship Monitor: National Entrepreneurial Assessment USA 2003 Executive Report*, p. 7. See http://www.kauffman.org/pdf/gem_2003_report.pdf.
[21] *The Innovation-Entrepreneurship NEXUS: A National Assessment of Entrepreneurship and Regional Economic Growth and Development.* Powell, Ohio: Advanced Research Technologies, LLC, April 2005.
[22] *A Governor's Guide to Strengthening State Entrepreneurship Policy*, National Governors Association, 1999.

Another program aimed at encouraging entrepreneurship and networking among entrepreneurs is the Entrepreneurial League System (ELS), which is being organized by Advantage Valley in the Charleston and Huntington area. The concept behind ELS is that entrepreneurs need a set of skills (technical skills, managerial skills, entrepreneurial skills, and personal maturity skills) and that each entrepreneur offers a certain level of each of these skills. Organizations implement the ELS to identify and recruit entrepreneurs, assess their skills, help them develop a game plan, bring them together with other entrepreneurs at a similar skill level, and help them obtain assistance from appropriate service providers. Other local and regional economic development agencies also provide support for entrepreneurs and start-up companies.

In addition, West Virginia has a small cadre of service providers—law firms, accounting firms, etc.—with staff experienced in working with entrepreneurs and start-up companies. Although not the case 5 or 6 years ago, this expertise has expanded as the number of technology companies has increased. Entrepreneurs interviewed indicated that they were able to obtain the services they require.

But, West Virginia lacks entrepreneurs with a track record of forming and growing successful new technology companies. Entrepreneurs reported that it is difficult to put together a management team for a new venture. Experienced CEOs, chief operations officers, chief financial officers, and senior technical employees need to be recruited from outside the region. This results, in part, from the fact that, historically, West Virginia's industry base has been composed of large corporations. Its citizens do not have a history of entrepreneurship, and many of those interviewed felt that the state's residents tend to be risk averse. Because entrepreneurial activity has been limited, there are few role models and few opportunities for technology entrepreneurs to interact. This lack of critical mass of entrepreneurs is compounded by geographic distance, although some regions are beginning to provide opportunities for networking (such as the Entrepreneurial Forum held in the Eastern Panhandle).

Capital Markets

Why They're Important

Most people realize that the process of discovery and development of new technologies is very expensive, in some cases, costing millions of dollars. However, many people do not realize that the costs of developing and taking a technology product or service to market are also very substantial. Major costs incurred after the research has been completed include those of assessing the market to determine the competition, the likely market, and the price points for competitive advantage; developing a prototype; preparing a marketing and sales plan; and scaling up for manufacturing. Finally, actual product distribution, sales, and marketing must be undertaken. Sufficient capital must be available to fund these activities for business growth and economic development to occur.

Yet, few sources of funding bridge the gap between discovery and business start-up and expansion. Research conducted by Lewis Branscomb and Philip Auerswald for the U.S. Department of Commerce's NIST found that "efficient markets do not exist for allocating risk capital to early-stage technology ventures."[23] The sources typically tapped to address this gap include angel investors, venture funds that invest at the seed and early stage, and publicly and privately supported university and nonuniversity programs specifically created for this purpose. Figure 8 shows the amounts and types of capital needed by technology companies at various stages of their development.

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[23] Branscomb, L. and P. Auerswald. *Between Inventions and Innovation: An Analysis of Funding for Early-Stage Technology Development.* National Institute of Standards and Technology, U.S. Department of Commerce, 2002.

Figure 8: Technology Commercialization Financing Needs

	R&D	Translational Research and Commercialization	Pre-seed/Seed	Start-Up	Expansion
ACTIVITIES	Conduct R&D Identify discoveries with possible commercial potential	Assess potential of technology Identify market Demonstrate proof of concept at lab scale Protect IP Optimize engineering License or form business	Develop prototype Test and validate Prepare business strategy Establish business function Secure initial financing	Put management team in place Secure follow-on financing Staff up for sales and marketing Begin initial sales and marketing	Begin full-scale production
FINANCING SOURCES	Conventional peer-reviewed federal grant support	• Within university: Grants funded with university, state, or industry dollars • Nonuniversity: Grants funded by public and philanthropic support • SBIR I	• Friends and family • Pre-eed/seed funds • Angel investors • SBIR II	• Early seed-stage venture capital • Publicly supported investment funds	• Venture funds • Equity • Commercial debt • Industry (strategic alliances, mergers, and acquisitions)
LEVEL OF INVESTMENT	Varies	$25,000 to $250,000	$250,000 to $1 million	$1 million to $2 million	> $2 million

Where West Virginia Stands

West Virginia lacks a fully developed risk capital market able to meet the needs of technology firms at various stages of their product life cycle, particularly at the very early commercialization and pre-seed/seed stages, although the state has helped increase the availability of venture capital. West Virginia companies received only $14 million in venture capital investments between 1999 and 2006 (Table 5). Investors indicated that, to date, West Virginia has not had a pipeline of companies that have reached the stage at which they are considered investment grade. Entrepreneurs indicated that venture capitalists from outside the region often consider a location in West Virginia as a negative because they do not think that West Virginia has a technology base or they think that any firm located in West Virginia must be a “lifestyle” company, a company created to enable its owner to live in a way and place of his or her choosing rather than a firm committed to achieving growth.

Table 5: Venture Capital Investments in West Virginia, 1999-Q3, 2006 ($ in millions)

Company	Industry	# of VC Deals	Year(s) Investments Occurred	Total $ Invested (Millions)
Applications Gateway	Business Applications Software	2	2000	3.00
ImageTree	Vertical Market Applications Software	1	2005	N/A
Plethora Technology	Connectivity and Communications Software	2	2003, 2005	1.25
SecureMethods	Network and Systems Management Software	3	1999, 2003, 2005	3.84
Threewide	Financial Institutions and Services	3	2001, 2002, 2004	1.77
Vested Health	Managed Care	2	2002, 2004	4.03
Total Investments in West Virginia		**13**		**13.89**

Source: Battelle analysis of Thomson Venture Xpert database.

The West Virginia Jobs Investment Trust (JIT) is a public venture capital fund. In addition to investing directly in companies, JIT invested $4 million each in the following private venture funds that agreed to have locations in West Virginia and to make a good faith effort to invest in West Virginia companies: Adena Ventures, Anthem Capital, Mountaineer Capital LP, PA Early Stage Partners, Toucan Capital, and Walker Ventures. Of these, only Mountaineer Capital is headquartered in West Virginia. To date, only Mountaineer Capital and Adena Ventures have invested in West Virginia companies. Table 6 shows venture capital investments by venture capital firms with locations in West Virginia between 1999 and 2006. (These data include all investments by these funds regardless of where the investment was made.) JIT, PA Early Stage Partners, and Anthem Capital were the only funds that invested at the seed stage, the stage at which many of West Virginia's technology companies need capital.

Table 6: Investments by Venture Capital Firms With West Virginia Locations, by Investment Stage, 1999–2006

Fund	Seed	Round	Round	Stage	Restart	Debt/Nonequity	Equity
Fourth Venture Investment Group		3	1			1	
Mountaineer Capital		5	1				1
West Virginia JIT	1	5	3	1		3	2
PA Early Stage Partners	5	45	22	20	6	6	
Adena Ventures		7	3	1		2	
Catterton Partners		10	7	3	5	1	
Anthem Capital	3	17	17	19	4	15	
Walker Ventures		23	15	11	1	13	

Source: Battelle analysis of Thomson Venture Xpert database.

Battelle
The Business of Innovation

West Virginia does not have an organized angel investment community and has few sources of commercialization and pre-seed funding. WVHTC's INNOVA provides early-stage investment from $50,000 to $150,000; but, the total amount available for investment is only about $1.3 million, with $900,000 presently uncommitted. JIT also invests in early-stage companies, but, again, resources are limited. WVU and MU have little access to resources to fund the proof-of-concept activities necessary to turn discoveries into technology with commercial applications.

Quality of Life

Why It's Important

Quality-of-life factors are critically important to high-technology companies competing for skilled technical workers. Young workers are highly mobile and can locate almost anywhere they want. Survey research shows that recreational and lifestyle amenities and environmental quality are the top-ranked location factors of high-technology firms.

Where West Virginia Stands

West Virginia's recreational and lifestyle amenities make it an attractive location for many people. Again and again, interviewees indicated that natural beauty and high quality of life make West Virginia a very attractive place to live. The lower cost of housing, shorter commutes, and low crime rates attract workers tired of living in more congested metropolitan areas. CEOs indicated that there is a ready source of talent in terms of West Virginians who have left the state to pursue employment opportunities but who are anxious to return if they could obtain a quality job.

Summary

West Virginia's strengths include its large number of nonprofit and federal research institutions; its growing academic research base at MU and WVU, with a focus on technology transfer and commercialization; its productive workforce; and its recreational amenities and high quality of life. State and regional organizations are creating the infrastructure needed to support TBED, and the results of such efforts are being seen in the state's growing technology sector. But, West Virginia also faces challenges that need to be addressed. The technology sector is still small; the educational attainment of the population, while improving, is still low; entrepreneurial and management talent is difficult to find; and start-up and emerging firms have difficulty obtaining capital. Because of the geography of the state, there are few significant population centers and greater collaboration

Competitive Advantages

- Presence of a large number of nonprofit and federal research institutions
- Growing academic research base
- Increased focus on tech transfer and commercialization at MU and WVU
- Growing technology sector, particularly in North Central West Virginia
- Highly productive workforce
- Quality college graduates
- Growing entrepreneurial support infrastructure
- Quality of life that is attractive to many people

Challenges

- Small base of technology industry
- Low educational attainment of population
- Lack of entrepreneurial talent
- Insufficient sources of risk capital, particularly at the commercialization, pre-seed, and seed stages
- Lack of entrepreneurial and management talent
- Little regional collaboration because of both geography and tradition
- Conservative and risk-averse population
- Image of West Virginia inconsistent with a tech-based economy

is needed on a statewide basis. But, as discussed below, West Virginia also has opportunities that could be realized to grow its technology sectors.

OPPORTUNITIES AND HOW TO REALIZE THEM

Identifying West Virginia's Technology Opportunities

West Virginia is poised to diversify its economy by growing its technology sectors. Battelle's analysis identified the following opportunities that could be leveraged to achieve this:

- ***Opportunities exist for greater commercialization of technology developed within the state's research institutions.*** As West Virginia's universities continue to grow their R&D bases, a commitment to invest in and encourage commercialization of research findings could lead to an increase in the number of start-up companies. Also, as West Virginia's colleges and universities add faculty and researchers, the recruitment of entrepreneurial faculty could help accelerate this process.
- ***The nation's increased focus on energy independence and alternative fuels is a tremendous opportunity for West Virginia*** with its historic strengths in energy R&D and its strong energy industry sector. As home to the NETL, West Virginia can take advantage of the resources of the NETL, as well as the strong energy R&D programs at WVU and the Rahall Transportation Institute at MU, to develop solutions to meet the nation's growing need for alternative energy sources.
- ***West Virginia's lower cost of living and high quality of life could be used to attract technical talent and technology companies to relocate to the state.*** West Virginia is close to the technology corridors in Northern Virginia and along I-270 in Maryland. As these regions become increasingly congested, West Virginia offers an alternative location that is still nearby existing clients. Concerns regarding security also may encourage locations outside the Washington, DC, metropolitan area. Graduates and alumni of West Virginia's colleges and universities who would be willing to return if employment opportunities were available represent one source of technical talent.
- ***West Virginia could attract additional federal operations that desire a secure location outside of, but close to, the Washington metropolitan area.*** In the aftermath of the 9/11 terrorist attacks, federal agencies have begun and will continue to move certain operations outside the Washington, DC, area. West Virginia is distant enough to be considered secure, but close enough to allow employees to travel to and from DC as needed.
- ***West Virginia has a cadre of highly educated and experienced workers and R&D laboratories and facilities at the site of the former Union Carbide R&D Headquarters that are available to grow a technology cluster in the greater Charleston region.*** The South Charleston Technology Park, former site of the R&D headquarters of Union Carbide Corporation, is a 650-acre site that includes 800,000 square feet of engineering, chemical, R&D, computer, and product development space. Many of the Ph.D.s laid off when Dow bought Union Carbide still reside in the region and are a source of talent that is and can be further tapped. MATRIC, a nonprofit organization formed in 2002, was created to capitalize on this R&D talent. MATRIC conducts research and facilitates commercialization of products in three areas: chemical and environmental technologies, health and life sciences, and advanced engineering systems. To date, MATRIC, with a staff of 51 people, 21 of whom are Ph.D.s, has won $8 million worth of competitive projects and spun out the following three companies:

- Transparent Armor, LLC, which focuses on developing and producing a new, strong, transparent polymer
- Mid-Atlantic Fuels, which is developing a biodiesel plant
- Energy Engineering R&D, which uses a process to clean natural gas pipelines.

Threats to Moving Forward

West Virginia Research Challenge Fund

West Virginia's Research Challenge Fund receives 0.5 percent of the state's racetrack video lottery proceeds. This currently generates $4 million annually that can be invested in building West Virginia's R&D base. *Vision 2015* proposes increasing the proportion incrementally to 5 percent by 2015 or $40 million annually.

Realizing the above opportunities will require significant investments to expand the state's R&D base and TBED efforts if West Virginia is to be competitive. Although a proposal is pending (text box at right) that would significantly increase West Virginia's contribution to its Research Challenge Fund, the state has, historically, not committed the same level of resources as its peer, competitor, and neighbor states to build an infrastructure to support technology companies. Even states with limited resources similar to West Virginia, such as North and South Dakota, are investing in state-supported centers of excellence and providing funding and support for commercialization. The following are examples of the type of investment that will be required in West Virginia.

Kentucky's Research Challenge Trust Fund

In 1997, the Kentucky legislature passed the Kentucky Postsecondary Education Improvement Act, which created the Research Challenge Trust Fund. The program provides funds for Kentucky's universities to attract and retain renowned faculty and researchers. The legislature has appropriated $350 million over 6 years to the fund. These dollars must be matched on a 1:1 basis with private contributions.

The short-term goals of the program are to (1) grow the universities' endowments, (2) increase the number of endowed chairs and professorships, and (3) generate increases in externally sponsored research. Longer-term goals are to stimulate business and job creation and to stimulate the transition to a knowledge-based economy. The program requires that 70 percent of all funds be targeted to the following five areas:

- Human health and development
- Biosciences
- Materials science and advanced manufacturing
- Information technology and communications
- Environmental and energy technologies.

Since inception, 111 endowed chairs and 176 endowed professorships have been created and the market value of the universities' research endowment has increased by 94 percent, growing from $453.5 million to $877.9 million. Extramural R&D has increased by 76 percent, from $105.2 million to $185 million.[24]

[24] "Leveraging Research Dollars," presentation by Sandra Woodley, Vice President for Finance, Kentucky Council on Postsecondary Education, September 19, 2005.

Maine S&T Investments

The State of Maine adopted a Science and Technology Action Plan in 2005 that calls for increasing the state's R&D base to $1 billion by 2010. To achieve this, the state has proposed a state investment in R&D of $120 million annually. This proposal follows a series of significant investments since 2000 including the following:

- $42 million in its Biomedical Research Fund, which has attracted more than $275 million in federal and private funds
- More than $90 million invested in the University of Maine System
- $25 million invested in the Maine Technology Institute (MTI), a statewide TBED organization created by the Legislature in 1999 to encourage, promote, stimulate, and support R&D activity leading to the commercialization of new products and services in the state's technology-intensive industrial sectors.[25]

According to a recent evaluation of MTI, employment in MTI-funded companies surveyed has risen by over 600, a growth rate of 6.2 percent, compared with 0.9 percent for the Maine economy as a whole between 2001 and 2006. The evaluation also shows that revenues from MTI companies equaled or exceeded $100 million by 2006.

Many of Maine's science and technology investments have been funded through bond issues.

Ohio's Third Frontier Project

Ohio's Third Frontier Project is a 10-year, $1.6 billion initiative to expand Ohio's high-technology research capabilities and promote innovation and company formation. The initiative is funding projects to build world-class research capacity, support early-stage capital formation, and finance advanced manufacturing technologies.

Oklahoma's EDGE Endowment

Oklahoma created an Economic Development Generating Excellence (EDGE) Endowment Fund to provide funding to grow the state's academic research base. It is proposed that $1 billion be invested in the fund over a multiyear time frame. The Legislature appropriated the first $150 million for EDGE in 2006, and the Governor has proposed that another $50 million be invested in 2007. EDGE funds will be used to recruit faculty, compete for federal centers of excellence, and provide investment capital to support commercialization.

Pennsylvania Energy Independence Fund

Pennsylvania has a long history of making significant investments to build its technology infrastructure. The Commonwealth invests approximately $27 million annually in its Ben Franklin Technology Partners program supporting regional centers that provide seed capital and support to start-up and emerging technology companies. The Commonwealth invested $100 million of its tobacco settlement dollars to create Life Sciences Greenhouses, comprehensive centers for commercialization of bioscience research, and another $60 million in four venture capital funds. In January 2007, the Governor proposed spending

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[25] Maine Office of Innovation. *A Science and Technology Action Plan for Maine 2005,* www.maineinnovation.com/studies_reports/pdfs/science_technology_action_plan_2005.pdf.

$850 million to create an Energy Independence Fund to make Pennsylvania a leader in the clean energy sector.

Additional factors that could impact West Virginia's ability to capitalize on its technology opportunities include the following:

- Demands on the federal budget could lead to a reduction in the flow of federal dollars to West Virginia.
- Without indigenous resources to commercialize technology in-state, West Virginia's research institutions could produce technology that will be commercialized elsewhere.
- West Virginia could begin to generate more start-up companies, but they will relocate if unable to obtain the talent and/or investment capital needed to expand.

These issues will need to be addressed.

Realizing West Virginia's Technology Opportunities

West Virginia has strengths on which to build; but, capitalizing on these opportunities will require that West Virginia address existing gaps in its technology infrastructure. Battelle's analysis identified the following four key gaps facing West Virginia in building its technology economy:

- **Talent.** To accelerate the growth of its technology sectors, West Virginia must be able to recruit world-class researchers to its universities and research institutions, retain its talented graduates, upgrade the skills of its workers, provide training for technicians and production workers, encourage its high school graduates to continue their education, and ensure that students are well prepared in science and math at the K-12 level.
- **Early-stage seed capital.** West Virginia has three capital gaps; the first is for funding for translational research and commercialization. This funding is in the range of $50,000 to $250,000 needed for proof-of-concept activities including preliminary market assessments, prototype development, and engineering optimization. The second gap is at the early-stage, pre-seed and seed capital stage from $200,000 to $1 million. The third gap is for risk capital for companies that are not appropriate targets for venture capital financing. These technology companies may be unable to provide the rate of return required by a venture capitalist or may not have an exit strategy. Also, firms within certain industry segments such as advanced manufacturing (e.g., materials) and information technologies and communications may need debt financing to cover operating expenses and equipment rather than equity; yet, they may be unable to obtain conventional lending because they are still pre-revenue, lacking cash flow, collateral, and traditional assets.

Key Gaps

- Talent
- Early-stage seed capital
- Entrepreneurial know-how
- Image

- **Entrepreneurial know-how.** West Virginia, historically, has not had an entrepreneurial culture with large companies dominating the state's economy. Any region without a track record of forming and growing successful technology companies lacks a supply of "serial" entrepreneurs, entrepreneurs who have both successfully and sometimes unsuccessfully started and grown several technology companies. As a result, there are few role models or experienced entrepreneurs to mentor aspiring entrepreneurs. Until West Virginia has a high churn rate of new-firm births and deaths, the state must find ways to attract, nurture, and support entrepreneurial and management talent. While several entrepreneurial support programs have been put in place, most of these organizations are resource poor and small scale. The challenge will be to organize these resources into a seamless commercialization assistance network.

- **Image.** CEOs, representatives of higher education, and public and private leaders interviewed for this project expressed the same concern—negative stereotypes of West Virginia persist and impact the state's ability to raise capital, recruit talent, and attract technology companies. The lack of awareness of the technology assets of West Virginia exists not only in people unfamiliar with West Virginia, but with many West Virginians as well. Efforts will be needed to change this image, both internally and externally, and to better educate both policymakers and the general citizenry on the technology economy and West Virginia's role in it.

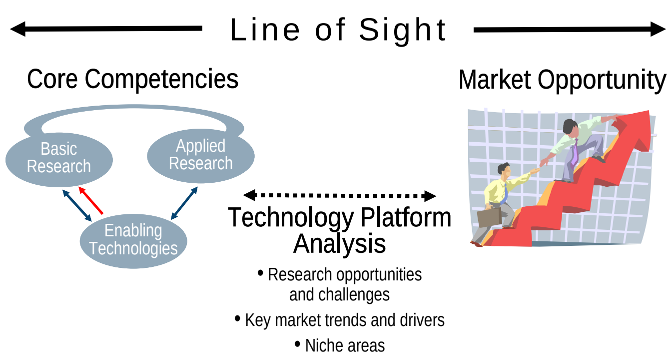
In summary, West Virginia has had great success in attracting federal R&D dollars and continues to build its academic and nonprofit research base. Investments in West Virginia during the past decade are increasing the number of technology jobs. But, while West Virginia is changing, perceptions are lagging and the state still faces major challenges in accelerating the growth of its technology economy.

West Virginia's resources are limited. Thus, it is important that, in addition to addressing these gaps, West Virginia focus strategically on those technology areas in which the state has a competitive advantage. The state's research strengths, core competencies, and the technology areas they suggest for focus are discussed in the next chapter of this report.

West Virginia's Research Core Competencies

The successful translation of research strengths into economic development opportunities requires recognition of the importance of "market-driven" processes. The traditional model of commercialization assumes a "research-driven" approach to commercialization. This research-driven commercialization process proceeds in a pipeline fashion—basic research, major scientific breakthrough, applied research, product development, manufacturing, and marketing. The research-driven approach is too divorced from commercialization and product development and has uncertain economic value. The market-driven approach recognizes that commercialization is a highly interactive process involving close ties between research activities and business development activities. Success depends, as the Council on Competitiveness points out, "on a team effort that includes carefully focused research, design for manufacturing, attention to quality, and continuous market feedback."[26]

Figure 9: Line of Sight From Core Competencies to Market Opportunity Through Technology Platforms



As seen in Figure 9, the components of a core competency bring together basic research, enabling technologies, and applied research with a "line of sight" that moves seamlessly to address market opportunities and can form robust technology platforms. Core competencies that lack this linkage and connection to needs and market opportunities offer more limited development opportunities.

DEFINING CORE COMPETENCIES

No one single source of information identifies core research competencies and focus areas. Rather, various integrated and complementary analyses are required to identify a state's current position and areas of focus that may lead or contribute to future technology sector growth.

The concept of core competencies is widely heralded by industry to advance competitive advantage. Gary Hamel and C.K. Prahalad in their landmark study, *Competing for the Future*, explain how a focus on core competencies can improve competitiveness:

> To successfully compete for the future, a company must be capable of enlarging its opportunity horizon. This requires top management to conceive of the company as a portfolio of core competencies rather than a portfolio of individual business units . . . Core competencies are the gateways to future opportunities. Leadership in a core competence represents a potentiality that is released when imaginative new ways of exploiting that core competence are envisioned. [27]

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[26] Council on Competitiveness, *Picking Up the Pace: The Commercial Challenge to American Innovation* (Washington, DC: Council on Competitiveness), pp. 9-10.
[27] Hamel, G., and C. K. Prahalad. *Competing for the Future*. Harvard Business School Press: Boston, MA, 1994.

Three tests can be used to identify a core competency:

1. Is it a significant source of competitive differentiation? (Does it provide a unique signature for the state?)
2. Does it transcend a single business? (Does it cover a range of businesses, both current and new?)
3. Is it hard for competitors to imitate? (Are there significant barriers to entry?)

From an economic-development perspective, core competencies represent a "critical mass" of know-how. It is through core competencies that a position in emerging technologies can best be gained. Emerging technologies not tied to core competencies require starting from scratch with major investments, rather than leveraging existing strengths.

Quantitative Analysis

Identifies research strengths through statistical analysis that includes the following:

- R&D grant awards
- Publications
- Patents
- Use of OmniViz™ clustering analysis of patent and grant awards to identify research and technology areas where both concentration of activity and excellence are demonstrated.

Battelle has developed a rigorous and robust approach to assessing a state's core competencies. It involves (1) an in-depth analysis of patent and federal grant awards, (2) a specialized cluster analysis that examines how grants and patents relate to one another, and (3) validation from interviews with industry executives and university officials.

Battelle's approach to assessing core competencies in this project included three steps:

- Step 1: Identify research strengths through statistical analysis of R&D grant awards, publications and patents. Battelle examined West Virginia's position in university research funding and publications strength to identify research core competencies. For industry-related core competency areas, Battelle assessed West Virginia's position by analyzing patents to identify industry R&D and technology strengths.
- Step 2: Conduct cluster analysis of patent and federal grant awards. Further identification of core competency areas was achieved through an analysis of West Virginia's 1,371 patent awards and more than 1,289 federal research grant awards from the NIH, NSF, and other federal agencies between 2000 and the second quarter of 2006. Battelle has developed proprietary textual information clustering software that provides unique insight into research themes and strength areas. The clustering tool, known as OmniViz™, uses textual-based correlations and clustering algorithms to cluster research fields into grouped strength areas. OmniViz™ analyzes the full textual content of input records (either research grant or patent information). The result of this cluster analysis is to identify key themes based on concentration of activity in university research grants and industry/institutional patents.
- Step 3: Interviews of key leadership and researchers at the state's universities, federal and nonprofit research laboratories. Battelle interviews researchers and industry officials to validate the findings from the quantitative analysis and to identify any new, emerging areas of research excellence. Battelle conducted extensive interviews at WVU, MU, WJU, NETL, NIOSH, and the WVHTC. These interviews were used to validate the core competencies and to identify the proposed technology platforms.

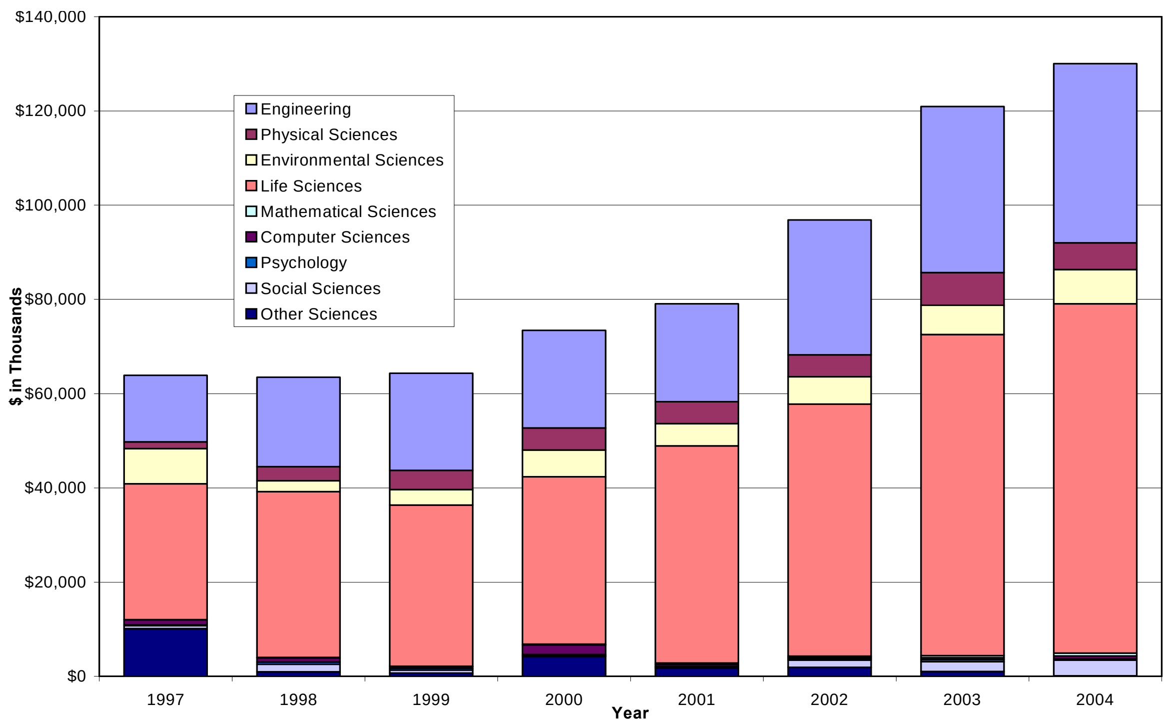
QUANTITATIVE ASSESSMENT OF WEST VIRGINIA'S RESEARCH STRENGTHS

Academic R&D

As discussed previously, West Virginia's total R&D base, including the R&D expenditures of West Virginia's industry, research laboratories and academic institutions, was $538 million in FY 2003. Academic R&D expenditures accounted for about 23 percent of the total, or $121 million. Total academic expenditures grew to $145 million in FY 2005. As a first step in identifying areas of research strength, Battelle examined how these resources are distributed by discipline. Unfortunately, data are not available to examine industrial and other research institution expenditures in the same way.

The life sciences, here defined as agricultural, medical, and biological sciences, account for an increasing percentage of West Virginia's academic R&D expenditures, as they have nationally. Fifty-seven percent of total academic R&D expenditures were in the life sciences in FY 2004; life sciences accounted for 45 percent in FY 1997 (Figure 10). Expenditures for engineering—including aeronautical, astronautical, biomedical, chemical, civil, electrical, mechanical, and materials engineering—rank second, accounting for almost 30 percent of total R&D expenditures in FY 2004, up from 22 percent in FY 1997.

Figure 10: Academic R&D Expenditures for West Virginia by Discipline and Year, 1997–2004



Source: *NSF Academic R&D Expenditures,FY 2004;* Battelle calculations.

West Virginia's share of total expenditures for engineering, at 29 percent, is significantly greater than the nation's at 15 percent. This greater share is likely because of greater relative activity in the sub-disciplines of chemical engineering, civil engineering, electrical engineering, materials engineering, and most notably, mechanical engineering, which accounts for 7 percent of all R&D expenditures in West Virginia. Environmental sciences R&D expenditures in West Virginia slightly exceed those for the nation, at 6 percent versus 5 percent. This can be explained by a relatively high share of activity in earth sciences.

However, the shares of total R&D expenditures for all other disciplines (except agricultural sciences and economics) are lower for West Virginia than for the United States (Table 7).

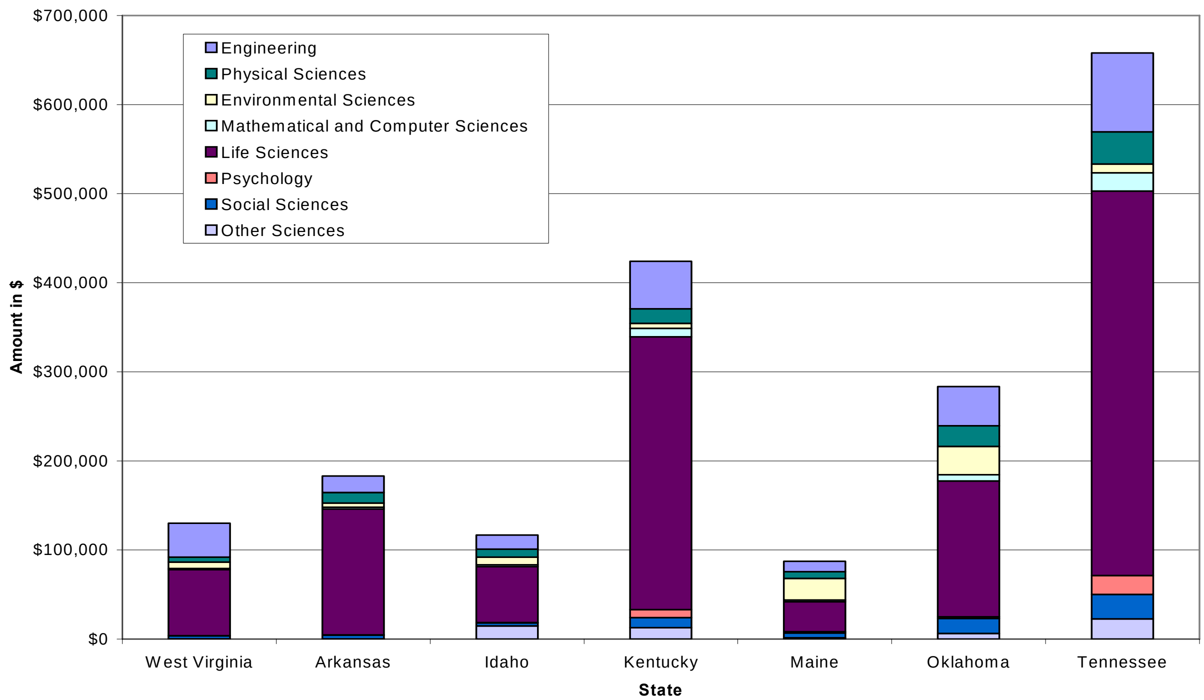
Table 7: Academic R&D Expenditures in West Virginia and United States, by Discipline, 2004

Discipline/Subdisciplines	West Virginia		United States	
	$ (thousands)	Share of Total	$ (thousands)	Share of Total
Aeronautical and Astronautical	8	0%	439,923	1%
Bioengineering/Biomedical Engineering	-	0%	369,848	1%
Chemical Engineering	4,977	4%	493,353	1%
Civil Engineering	8,025	6%	789,257	2%
Electrical Engineering	7,381	6%	1,437,535	3%
Mechanical Engineering	9,037	7%	867,475	2%
Metallurgical and Materials Engineering	5,379	4%	564,968	1%
Other Engineering	3,250	2%	1,349,668	3%
Total for Engineering	38,057	29%	6,312,027	15%
Astronomy	-	0%	420,254	1%
Chemistry	2,366	2%	1,316,897	3%
Physics	3,207	2%	1,522,134	4%
Other Physical Sciences	100	0%	285,746	1%
Total for Physical Sciences	5,673	4%	3,545,031	8%
Atmospheric	-	0%	415,645	1%
Earth Sciences	7,219	6%	829,609	2%
Oceanography	-	0%	776,498	2%
Other Environmental Sciences	28	0%	332,311	1%
Total for Environmental Sciences	7,247	6%	2,354,063	5%
Total for Mathematical Sciences	636	0%	449,968	1%
Total for Computer Sciences	596	0%	1,404,509	3%
Agricultural Sciences	16,891	13%	2,694,818	6%
Biological Sciences	15,217	12%	7,840,436	18%
Medical Sciences	40,446	31%	14,040,677	33%
Other Life Sciences	1,593	1%	1,074,369	3%
Total for Life Sciences	74,147	57%	25,650,300	60%
Total for Psychology	277	0%	782,481	2%
Economics	2,283	2%	316,615	1%
Political Science	168	0%	301,938	1%
Sociology	118	0%	355,429	1%
Other Social Sciences	740	1%	695,764	2%
Total for Social Sciences	3,309	3%	1,669,746	4%
Total for All Other Sciences	115	0%	776,956	2%
Total for All Disciplines	130,057	100%	42,945,081	100%

Source: *NSF Academic R&D Expenditures, FY 200;* Battelle calculations.

Compared with the designated benchmark states of Arkansas, Idaho, Kentucky, Maine, Okalahoma and Tennessee, West Virginia ranks near the middle for academic R&D expenditures in FY 2004 (Figure 11). Its total expenditures were greater than those of Idaho and Maine, but lower than those of the other four states.

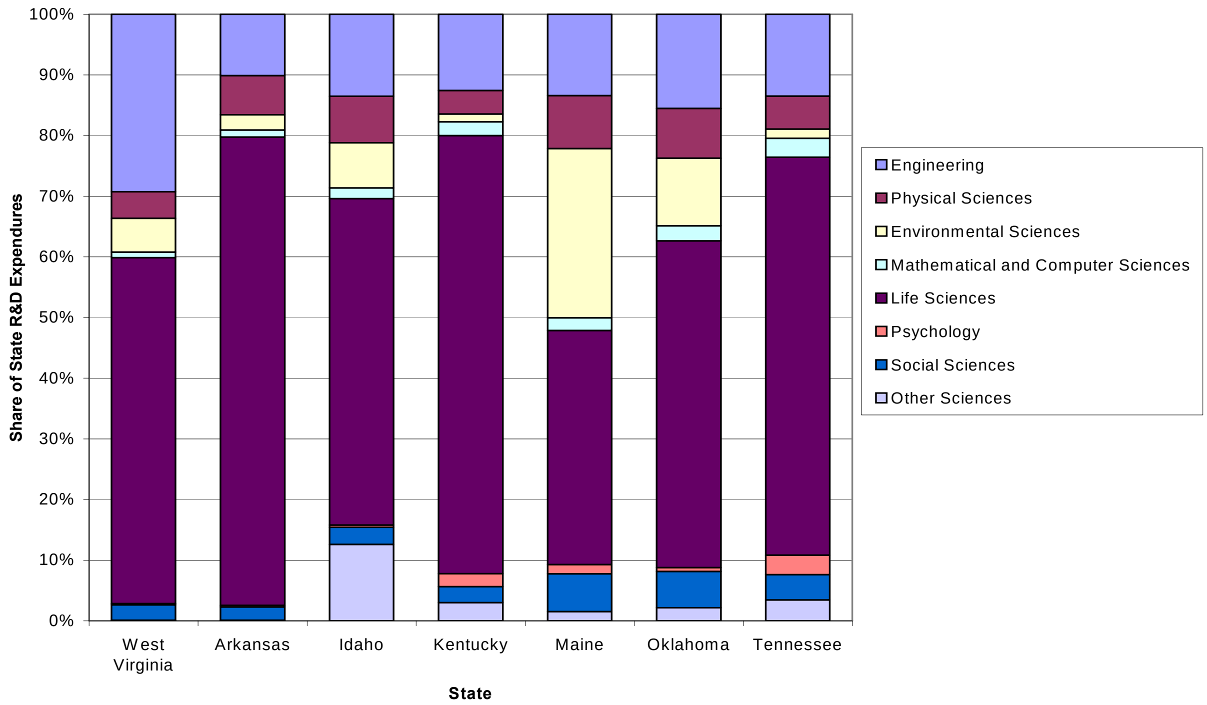
Figure 11: Academic R&D Expenditures for West Virginia and Benchmarks, by Discipline, 2004 ($ in thousands)



Source: *NSF Academic R&D Expenditures, FY 2004;* Battelle calculations.

Figure 12 illustrates the shares of total academic R&D expenditures for West Virginia and the benchmark states by discipline. Life sciences uniformly account for the majority of expenditures in each state. However, the share of academic expenditures for engineering is considerably higher in West Virginia than in any of the benchmark states. Conversely, the share of academic expenditures for psychology and other sciences is considerably lower in West Virginia than in most of the benchmark states.

Figure 12: Share of Academic R&D Expenditures for West Virginia and Benchmark States, by Discipline, 2004



Source: *NSF Academic R&D Expenditures, FY 2004;* Battelle calculations.

Federal R&D

An examination of federal R&D obligations shows that the U.S. Department of Energy (DOE) was the largest funding agency for West Virginia in FY 2003 accounting for approximately 43 percent of the total. This results, in part, from the presence of the NETL in Morgantown. The DOD accounted for 19 percent of the total. DOE and DoD R&D obligations accounted for roughly 95 percent of all federal funds received by West Virginia industry. The U.S. Department of Health and Human Services (HHS), which houses the NIH, and NASA each accounted for 11 percent of the total. HHS and NASA were particularly important funders for West Virginia's universities and colleges; the two agencies accounted for 58 percent of all federal funds received by West Virginia's universities and colleges. NASA R&D obligations to other nonprofits exceeded obligations to industry and academia combined (Table 8).

Table 8: Federal R&D Obligations to West Virginia, by Agency, 2003

Agency	Extramural: Industry	Extramural: Universities and Colleges	Extramural: Other Nonprofits	Extramural: State, Local Governments	Intramural	Total R&D
Total for West Virginia	160,289	49,699	30,165	2,279	124,961	367,393
Department of Agriculture	7	7,090	1,403	8	24,810	33,318
Department of Commerce	67	2,460	-	-	-	2,527
Department of Defense, Research	1,375	1,620	1,649	-	6,204	10,848
Department of Defense, Total Development	58,685	2,057	1,350	-	7,752	69,844
Department of Energy	92,719	3,655	1,275	-	59,107	156,756
Department of Health and Human Services	639	16,695	59	952	22,403	40,748
Department of the Interior	-	278	-	235	4,640	5,153
Department of Transportation	994	785	-	1,084	-	2,863
Environmental Protection Agency	-	946	-	-	45	991
National Aeronautics and Space Administration	5,116	11,914	24,419	-	-	41,449
National Science Foundation	687	2,199	10	-	-	2,896

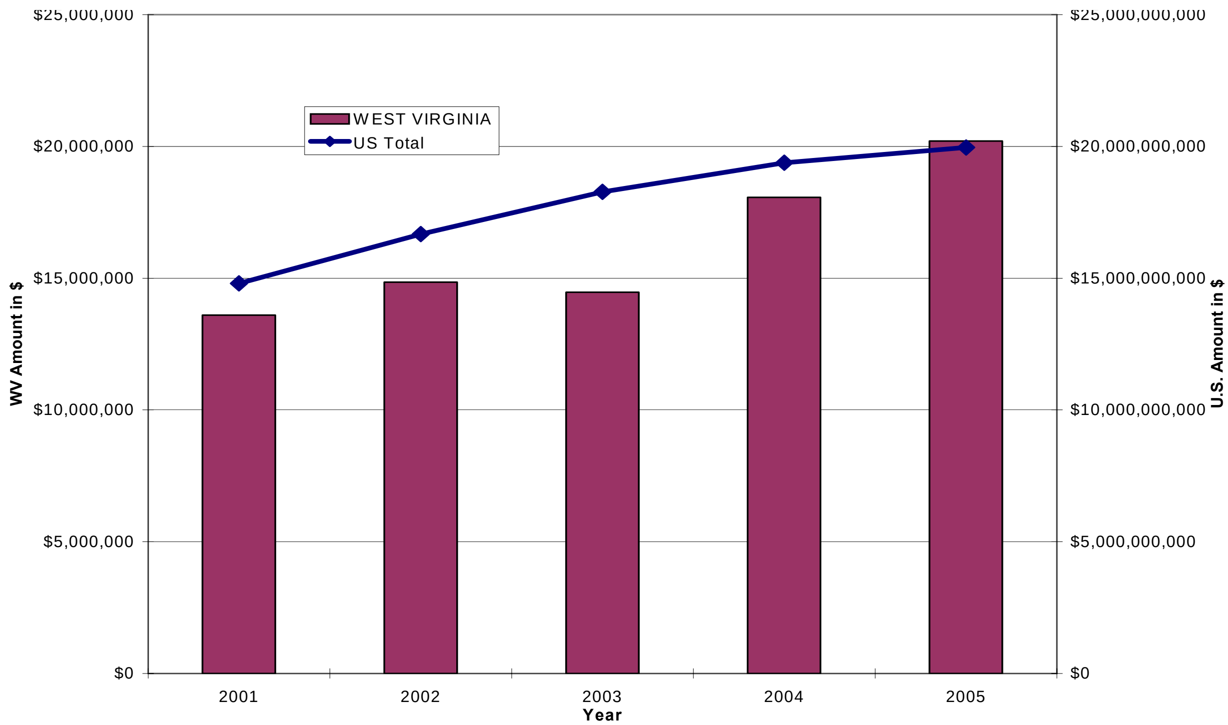
Source: NSF—Division of Science Resources Statistics, Science and Engineering State Profiles; Battelle calculations.

The NIH is the primary grant-making organization for biomedical and health-related research. Trends in NIH funding indicate a state's strength and competitiveness in biomedical and health science research and development activities. From 2001 to 2005, NIH funding to West Virginia increased from approximately $13 million to more than $20 million (Figure 13). From 2001 to 2005, NIH funding to West Virginia grew at a rate of 48.5 percent, which exceeded U.S. growth of approximately 35 percent.

Compared with the benchmark states, West Virginia received relatively little NIH funding from 2001 to 2005 (Figure 14). Only Idaho received less. However, while Idaho, Maine, and Oklahoma experienced decreases in NIH funding from 2004 to 2005, West Virginia joined Arkansas, Kentucky and Tennessee in experiencing gains in NIH research grants.

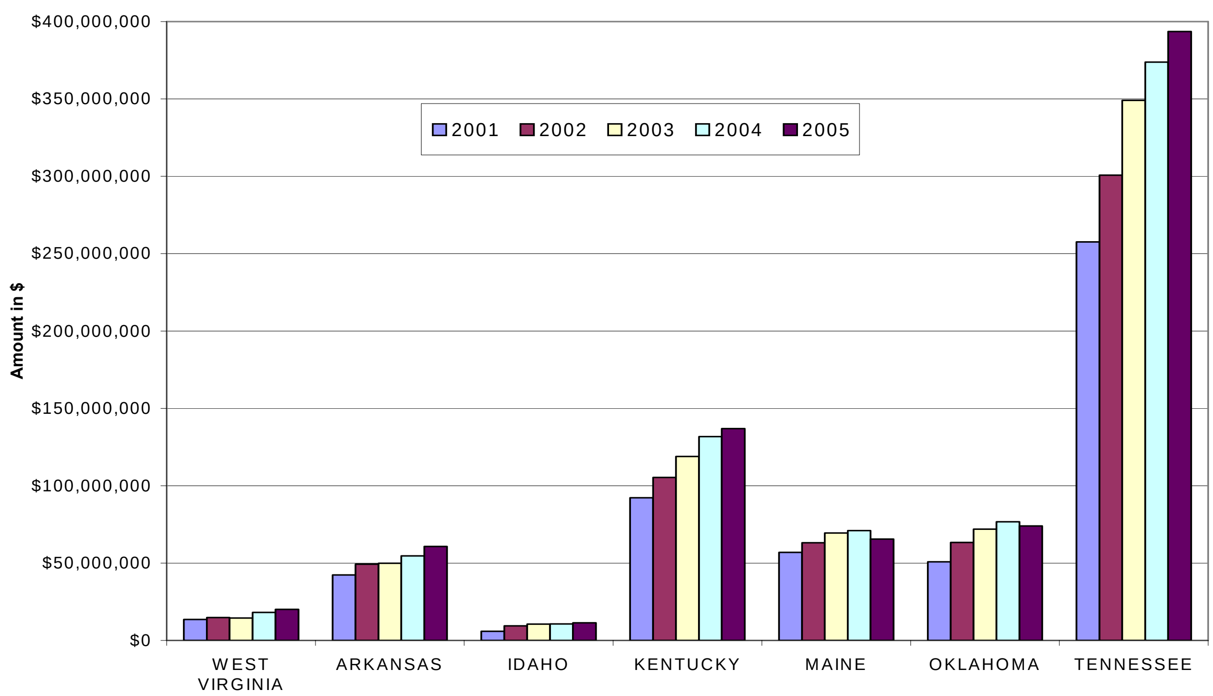
The 21 institutes and centers within NIH fund different fields within the broad spectrum of biomedical and health-related research. From 2003 to 2006, West Virginia received nearly $72.4 million in funding from NIH. The National Center for Research Resources (NCRR), which provides scientists with the environments and tools required to conduct their research, provided the majority of this funding. In addition, almost $10 million was awarded by the National Heart, Lung, and Blood Institute (NHLBI), $4.6 million by the National Cancer Institute (NCI), $3.6 million by the National Institute for Diabetes and Digestive and Kidney Diseases (NIDDK) and $3.2 million by the National Institute on Deafness and Other Communication Disorders (NIDCD) (Table 9).

Figure 13: NIH Funding to West Virginia and the United States, 2001–2005



Source: NIH Award Trends data and Battelle calculations.

Figure 14: NIH Funding to West Virginia Compared With Benchmark States, 2001–2005



Source: NIH Award Trends Data: Battelle calculations.

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Table 9: NIH Funding to West Virginia by NIH Institute or Center, FY 2003–August 2006

NIH Institute or Center	$ Amount
National Center for Research Resources (NCRR)	33,832,590
National Heart, Lung, and Blood Institute (NHLBI)	9,985,890
National Cancer Institute (NCI)	4,575,801
National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)	3,611,893
National Institute on Deafness and Other Communication Disorders (NIDCD)	3,207,388
National Institute on Aging (NIA)	2,606,518
National Institute on Allergy and Infectious Diseases (NIAID)	2,600,723
National Eye Institute (NEI)	1,810,281
National Institute of General Medical Sciences (NIGMS)	1,638,676
National Institute of Environmental Health Sciences (NIEHS)	1,572,099
National Institute of Child Health and Human Development (NICHD)	1,505,981
National Institute of Mental Health (NIMH)	1,434,290
National Institute on Alcohol Abuse and Alcoholism (NIAAA)	932,232
National Institute of Minority Health and Health Disparities (NCMHD)	755,814
National Institute of Dental and Craniofacial Research (NIDCR)	699,765
National Institute of Neurological Disorders and Stroke (NINDS)	687,279
National Center for Complementary and Alternative Medicine (NCCAM)	359,913
National Institute of Nursing Research (NINR)	214,354
National Institute of Biomedical Imaging and Bioengineering (NIBIB)	177,900
National Institute of Arthritis and Musculoskeletal and Skin Diseases (NIAMS)	146,000
National Library of Medicine (NLM)	36,078
Grand Total	72,391,465

Source: NIH Award Trends data: Battelle calculations.

The nearly $72.4 million in NIH funding to West Virginia from 2003 to 2006 was composed of awards to four organizations: Bluefield State College, MU, WVU, and the National Micrographics System of West Virginia (Table 10). The vast majority of award dollars went to WVU; primarily to the Departments of Internal Medicine, Otolaryngology, Physiology, and Microbiology/Immunology. At MU, the Department of Pharmacology received the greatest level of NIH funding, followed by the Department of Biochemistry. One private company, National Micrographics Systems of West Virginia, received an NIH award during this time period.

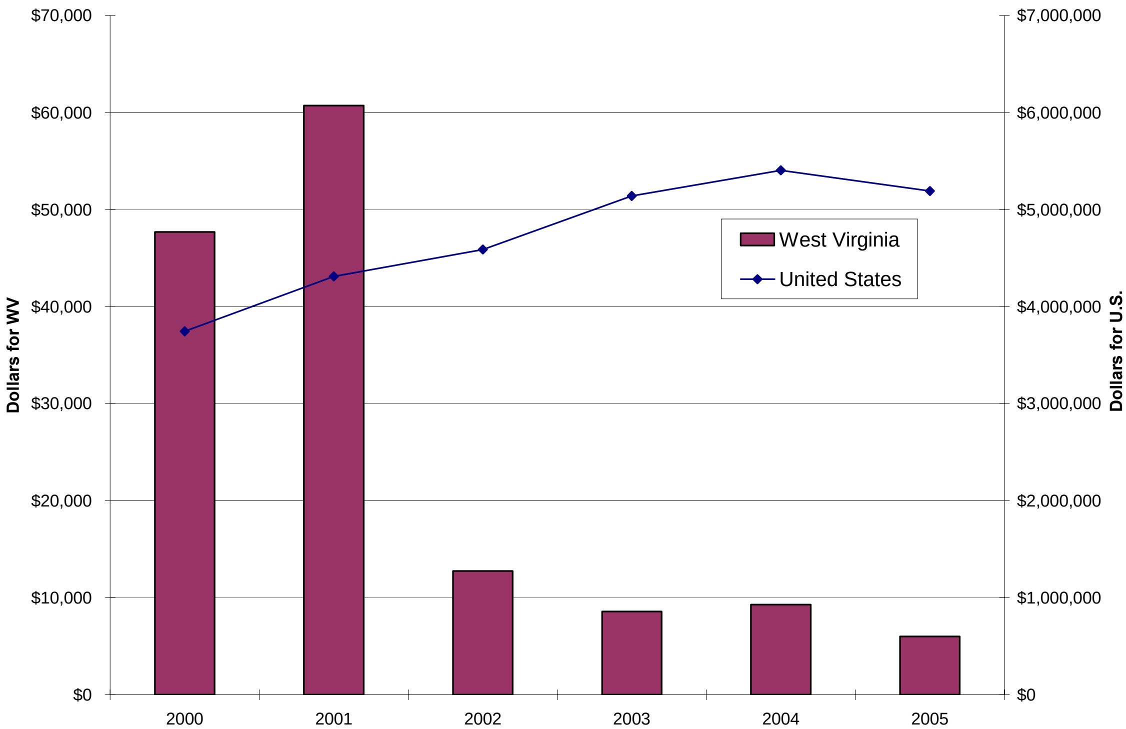
Table 10: NIH Funding to West Virginia by University and Department, FY 2003–August 2006

Institute/Organization	Department	$ Amount
Bluefield State College	Social Sciences	755,814
Marshall University	Biochemistry	6,119,968
	Biology	172,200
	Microbiology/Immun/Virology	295,717
	None	2,276,706
	Pharmacology	10,528,719
West Virginia University	Biochemistry	929,759
	Biology	2,277,593
	Chemistry	744,600
	Internal Medicine/Medicine	11,495,500
	Microbiology/Immun/Virology	6,506,673
	Miscellaneous	760,496
	None	1,180,573
	Obstetrics and Gynecology	519,424
	Ophthalmology	126,000
	Other Basic Sciences	124,640
	Otolaryngology	10,634,014
	Pathology	146,000
	Pediatrics	1,620,695
	Pharmacology	512,250
	Physiology	7,077,487
	Psychiatry	3,167,750
	Psychology	129,857
	Public Health and Prev Medicine	1,217,308
	Radiation-Diagnostic/Oncology	2,335,673
	Veterinary Sciences	699,971
National Micrographics Systems of West Virginia	N/A	36,078
Total		72,391,465

Source: NIH Award Trends data; Battelle calculations.

The NSF supports all fields of science and engineering research that are not related to biomedicine or health. From 2000 to 2005, NSF funding to West Virginia decreased sharply, due in large part to expiration of the National Radio Astronomy Observatory grant in 2002 (Figure 15). NSF funding to West Virginia is significantly lower than NIH funding, at $8 million in 2005 compared with $21 million in NIH awards.

Figure 15: NSF Funding to West Virginia and the United States, 2000–2005 ($ in thousands)



Source: NSF Budget Internet Information System

NSF has seven directorates, each of which oversees award funding for different fields of basic science and engineering research. From 2000 to 2006, West Virginia was awarded $60.7 million in NSF funding, of which $33.9 million was from the Directorate for Education and Human Resources (Table 11). (Note that the data in Figure 15 are for grant funding received from 2000 to 2005 and, therefore, include multiyear awards made prior to 2000. The data in Tables 11 and 12 include only grant awards made between 2000 and 2006.) The West Virginia Experimental Program to Stimulate Competitive Research (West Virginia EPSCoR) brought $20 million to the state between 2002 and 2006 to be used for growing the state's competitiveness in science, technology, engineering, and mathematics fields of research.

Table 11: NSF Funding to West Virginia by NSF Directorate and Division, 2000–2006

NSF Directorate	NSF Division	# of Awards	$ Amount
Directorate for Biological Sciences	Division of Biological Infrastructure	5	2,222,165
	Division of Environmental Biology	4	908,464
	Division of Integrative Organismal Biology	3	903,577
	Division of Molecular and Cellular Biosciences	2	188,815
	Total for Biological Sciences Directorate	14	4,223,021
Directorate for Computer and Information Science and Engineering	Division of Computer and Communication Foundations	4	887,192
	Division of Computer and Network Systems	7	2,396,478
	Division of Information and Intelligent Systems	5	1,807,763
	Total for Computer and Information Science and Engineering Directorate	16	5,091,433
Directorate for Education & Human Resources	Division of Elementary, Secondary and Informal Education	7	13,223,700
	Division of Graduate Education	1	1,516,164
	Division of Undergraduate Education	10	4,147,403
	Office of Experimental Program to Stimulate Competitive Research	8	14,598,872
	Total for Education and Human Resources Directorate	30	33,866,544
Directorate for Engineering	Chemical, Bioengineering, Environmental, and Transports Systems	1	280,000
	Civil, Mechanical, and Manufacturing Innovation	5	497,353
	Electrical Communications and Cyber Systems	4	686,240
	Industrial Innovation and Partnerships	14	3,802,122
	Total for Engineering Directorate	24	5,265,715
Directorate for Geosciences	Division of Atmospheric Sciences	6	1,904,495
	Division of Earth Sciences	4	264,172
	Division of Ocean Sciences	1	499,655
	Total for Geosciences Directorate	12	2,745,858
Directorate for Mathematical and Physical Sciences	Division of Chemistry	14	3,470,561
	Division of Materials Research	5	1,232,932
	Division of Mathematical Sciences	2	120,368
	Division of Physics	5	922,358
	Total for Mathematical and Physical Sciences Directorate	26	5,746,219
Directorate for Social, Behavioral, and Economic Sciences	Division of Behavioral and Cognitive Sciences	8	543,791
	Division of Social and Economic Sciences	2	163,073
	Total for Social, Behavioral & Economic Sciences Directorate	11	1,106,823
Other NSF Offices/Programs		11	2,632,526
Total for All Directorates		144	60,678,139

Source: NSF FastLane Database, 2006; Battelle calculations.

Table 12 shows NSF funding for research by West Virginia institutions from 2000 to 2006. WVU, including the WVU Research Corporation, WVU, and WVU Parkersburg, is the leading recipient, receiving $27 million between FY 2000 and FY 2006. The Higher Education Policy Commission (HEPC), the West Virginia Department of Education, the Appalachia Educational Laboratory, a private nonprofit organization), the Institute for Scientific Research (now part of WVHTC), the Treasury Franchise Center, and MU all received in excess of $2 million in NSF funding during this time period.

Table 12: NSF Funding to West Virginia by Institution, 2000–2006

Organization	$ Amount
West Virginia University Research Corporation	26,939,573
Higher Education Policy Commission	10,574,601
West Virginia Department of Education	6,241,995
Appalachia Educational Laboratory Inc	4,818,464
Institute for Scientific Research, Inc.	2,692,587
Administrative Resource Center, Treasury Franchise Center	2,562,187
Marshall University Research Corporation	2,391,918
Wheeling Jesuit University	807,512
State College and University Systems of West Virginia	799,678
Association of State Supervisors of Mathematics	584,081
Fairmont State College	428,672
West Virginia State University	221,391
Touchstone Research Laboratory Ltd.	199,974
Mountain State University	168,620
West Liberty State College	151,656
University of Charleston	147,960
J. S. Kanel and Associates LLC	100,000
VRGIS Corporation	100,000
Meadow River Enterprises, Inc.	99,981
Advanced Rolling Technologies LLC	99,968
ProLogic, Inc.	99,935
Redpoint Controls, LLC	99,774
PresSure Products Company Inc.	99,766
Terrasimco Incorporated	95,385
West Virginia Wesleyan College	83,585
Karst Waters Institute	33,375
West Virginia University at Parkersburg	30,000
Keesee, Amy M.	3,000
Beverage, Jason A.	2,500
Total for West Virginia	**60,678,139**

Source: NSF FastLane Database, 2006; Battelle calculations.

Industrial R&D

In 2003, West Virginia's manufacturing industries accounted for 81 percent of total industrial R&D expenditure (Table 13). The chemical industry accounted for most of this; but, the aerospace products and parts industry also spent a significant amount. Among nonmanufacturing industries in the state, the information industry reported the greatest level of R&D expenditure, followed by architectural, engineering, and related services.

Table 13: Industrial R&D Expenditures for West Virginia, by Industry, 2003

Industry	$ in Millions
Chemicals	112
Aerospace products and parts	33
Motor vehicles, trailers, and parts	9
Plastics and rubber products	6
Computer and electronic products	6
Other manufacturing	4
Electrical equipment, appliances, and components	3
Miscellaneous manufacturing	3
Primary metals	3
Manufacturing Industries Total	179
Information	9
Architectural, engineering, and related services	8
Other nonmanufacturing	5
Mining, extraction, and support activities	4
Wholesale trade	4
Retail trade	4
Computer systems design and related services	4
Scientific R&D services	1
Other professional, scientific, and technical services	1
Nonmanufacturing Industries Total	40
All Industries	219

Source: NSF—Division of Science Resources Statistics, *Survey of Industrial Research and Development: 2003.*

Publications and Citations Analysis

ISI data[28] provide specific insight regarding the volume of publications produced by academic departments and the influence, in terms of citations, that each department's work is having within its field. Battelle accessed the ISI data for West Virginia's research institutions, which included WVU, MU, and WJU, from 2001 to 2005. In determining areas of strength, the focus was on fields where West Virginia institutions had published at least 20 papers. Table 14 lists the number of papers and citations for West Virginia's research institutions in each field. The numbers in red show fields in which West Virginia's research institutions have a higher concentration of papers and/or citations relative to all U.S. institutions.

As judged by "impact relative to field," which compares the ratio of citations per publication for the state compared with that of the nation, no field within the biological sciences stands out as particularly

Explanation of ISI Publication Data Measures

Citation Quotients measure the concentration of paper citations in a particular field at an institution, relative to all U.S. institutions.

Papers Quotients measure the concentration of papers published in a particular field at an institution, relative to all U.S. institutions.

Impact Relative to Field measures the citations-to-papers ratio within an institution's field with respect to the citations-to-papers ratio of the same field within the United States.

Analysis Guidelines—For these measures a value greater than 1.0 indicates that the institution is relatively concentrated in a particular field, whereas a quotient less than 1.0 signifies relative underrepresentation. The minimum concentration threshold for declaring specialization in a particular field is somewhat open to interpretation, but Battelle defines it as a value of 1.2 or greater.

[28] ISI refers to the Thomson Scientific ISI Database of U.S. scientific papers and associated citations.

strong for West Virginia. Areas with a large number of papers include environment/ecology, pharmacology and toxicology, plant sciences, and oncogenesis and cancer research. However, the state does have strengths in multiple areas of the physical sciences, including "multidisciplinary" (a mix of journals with no obvious common theme), civil engineering, and engineering mathematics. Each West Virginia publication in these fields is cited at least 23 percent more frequently than the national average. Within the physical sciences, applied physics/condensed matter/materials science has a large number of publications.

Table 14: ISI Publication and Citation Data, 2001–2005

Research Fields with >20 Papers	Papers	Papers Quotient	Citations	Citations Quotient	Impact Relative to Field
Biological Sciences					
Psychology	264	2.26	638	2.82	0.68
Environment/Ecology	164	1.55	524	2.01	0.71
Pharmacology and Toxicology	163	2.31	747	2.85	0.68
Neurosciences and Behavior	158	0.91	839	0.88	0.53
Medical Research, Organs and Systems	116	0.98	640	1.40	0.78
Biochemistry and Biophysics	106	0.68	731	0.73	0.59
Plant Sciences	105	1.81	337	1.84	0.56
Oncogenesis and Cancer Research	99	1.37	791	1.57	0.63
Medical Research, General Topics	97	1.23	562	0.87	0.39
Organic Chemistry/Polymer Science	72	1.22	371	2.00	0.89
Cardiovascular and Respiratory Systems	70	0.93	401	1.24	0.73
Cell and Developmental Biology	69	1.02	291	0.41	0.22
Pediatrics	69	1.90	100	1.21	0.35
Cardiovascular & Hematology Research	67	0.83	449	0.91	0.60
Medical Research, Diagnosis and Treatment	65	0.78	234	0.86	0.61
Animal Sciences	59	1.40	136	2.10	0.82
Neurology	58	1.21	240	1.39	0.63
Surgery	57	1.48	153	1.79	0.66
General and Internal Medicine	56	1.06	453	1.09	0.57
Radiology, Nuclear Medicine and Imaging	54	1.30	317	2.56	1.07
Urology	47	1.40	243	2.04	0.79
Experimental Biology	45	1.67	59	0.50	0.16
Molecular Biology and Genetics	44	0.63	410	0.75	0.66
Environmental Medicine and Public Health	42	1.38	147	1.69	0.67
Oncology	39	0.66	415	1.04	0.86
Aquatic Sciences	38	0.94	53	0.65	0.38
Env. Studies, Geography and Development	38	2.31	42	2.52	0.60
Physiology	38	1.83	178	1.94	0.58
Microbiology	37	0.47	264	0.63	0.74
Pharmacology/Toxicology	37	1.59	124	1.96	0.68
Anesthesia and Intensive Care	36	1.27	148	2.16	0.93
Food Science/Nutrition	35	1.23	121	1.95	0.87
Environmental Engineering and Energy	34	1.40	46	0.93	0.37
Endocrinology, Nutrition and Metabolism	33	0.66	240	0.90	0.75

Table 14: ISI Publication and Citation Data, 2001–2005 (continued)

Research Fields with >20 Papers	Papers	Papers Quotient	Citations	Citations Quotient	Impact Relative to Field
Biological Sciences (continued)					
Research/Laboratory Medicine and Medical Tech	33	0.82	109	0.58	0.39
Health Care Sciences and Services	31	1.72	57	1.96	0.62
Entomology/Pest Control	30	1.24	32	0.97	0.43
Orthopedics, Rehabilitation and Sports Medicine	30	0.89	53	1.00	0.62
Otolaryngology	22	1.40	43	1.79	0.70
Animal and Plant Sciences	21	0.80	137	1.18	0.81
Gastroenterology and Hepatology	21	0.93	35	0.32	0.19
Immunology	20	0.26	59	0.10	0.22
Ophthalmology	20	0.98	35	0.75	0.41
Physical Sciences					
Applied Physics/Condensed Matter/Materials Science	153	0.88	606	1.28	0.79
Physics	92	0.72	366	0.69	0.53
Materials Science & Engineering	78	1.10	116	0.78	0.39
Mathematics	74	1.13	118	1.90	0.92
Organic Chemistry/Polymer Science	72	1.22	371	2.00	0.89
Physical Chemistry/Chemical Physics	68	0.75	229	0.79	0.57
Chemistry and Analysis	67	0.71	373	0.79	0.61
Earth Sciences	53	0.51	254	0.89	0.95
Chemical Engineering	49	2.16	103	2.64	0.67
Economics	47	0.81	51	0.68	0.46
Mechanical Engineering	44	0.97	67	1.18	0.67
Spectroscopy/Instrumentation/Analytical Sciences	41	0.83	174	1.30	0.86
Electrical and Electronic Engineering	34	0.61	67	0.87	0.78
Computer Science and Engineering	31	1.01	52	1.68	0.91
Multidisciplinary	30	0.53	287	1.42	1.46
Civil Engineering	25	0.98	53	2.20	1.23
Engineering Management/General	25	1.54	24	1.50	0.53
Chemistry	22	0.41	88	0.25	0.34
Engineering Mathematics	21	1.05	32	2.43	1.27

Source: Thomson Scientific ISI Publication Data, 2001–2005, with Battelle calculations.

On an institutional basis, MU's publications in molecular biology were cited 65 percent more frequently than the national average; but, MU published only 12 times in this field. The majority of MU publications were in the field of experimental biology, and the corresponding papers quotient suggests an unusually high concentration of publication activity in this field. Pediatrics is another strength area for MU in terms of ISI data. Similarly, WJU reports high publications and citations quotients in the fields of oncogenesis and cancer research, radiology, nuclear medicine and imaging, and urology. Most of these publications can be attributed to one outstanding researcher at the affiliated hospital. WVU does not appear to publish or be cited in any specific field at a level dramatically above the national average (Table 15).

Table 15: ISI Publication and Citation Data by Institution, 2001–2005

Research Field	Papers	Papers Quotient	Citations	Citations Quotient	Impact Relative to Field
Marshall University					
Experimental Biology	34	9.81	1	0.11	0.00
Medical Research, General Topics	28	2.76	126	2.55	0.30
Psychology	25	1.67	33	1.90	0.37
Pediatrics	24	5.15	36	5.68	0.36
Biochemistry and Biophysics	23	1.15	70	0.91	0.26
Pharmacology and Toxicology	19	2.09	34	1.69	0.26
Gastroenterology and Hepatology	16	5.52	25	2.97	0.18
Cardiovascular and Respiratory Systems	12	1.24	12	0.48	0.13
General and Internal Medicine	12	1.76	114	3.58	0.66
Molecular Biology and Genetics	12	1.33	282	6.72	1.65
West Virginia University					
Psychology	211	2.17	596	2.97	0.80
Environment/Ecology	153	1.74	515	2.23	0.75
Applied Physics/Condensed Matter/Materials Science	147	1.02	602	1.43	0.82
Pharmacology and Toxicology	144	2.45	713	3.07	0.73
Neurosciences and Behavior	140	0.97	824	0.97	0.59
Medical Research, Organs and Systems	108	1.10	639	1.58	0.83
Public Health and Health Care Science	107	1.78	209	1.85	0.61
Plant Sciences	100	2.08	315	1.94	0.54
Physics	90	0.85	362	0.77	0.53
Biochemistry and Biophysics	83	0.64	661	0.74	0.68
Wheeling Jesuit University					
Oncogenesis and Cancer Research	39	13.18	271	14.20	0.54
Radiology Nuclear Medicine and Imaging	32	18.87	231	49.37	1.32
Psychology	28	5.85	9	1.05	0.09
Neurosciences and Behavior	11	1.54	0	0.00	0.00
Urology	11	8.02	66	14.65	0.92
Oncology	7	2.90	21	1.40	0.24
Experimental Biology	2	1.81	0	0.00	0.00
Applied Physics/Condensed Matter/Materials Science	1	0.14	1	0.06	0.20
Chemistry	1	0.45	1	0.08	0.09
Computer Science and Engineering	1	0.80	0	0.00	0.00

Source: Thomson Scientific ISI Publication Data, 2001–2005, with Battelle calculations.

Patent Analysis

Examining patent activity is an additional way to consider the broad base of innovation across West Virginia. Patents represent the intellectual property (IP) generated or owned by companies and research institutions in the state. Through patents, companies and researchers protect their product innovations from being replicated. Battelle examined patent data as another indicator of areas of research and innovation strength in West Virginia. West Virginia inventors and assignees accounted for 1,371 patents between January 2000 and April 2006. In 2004, 100 utility patents were issued to West Virginia assignees and inventors, ranking the state 45th in number of patents issued to state residents.[29] West Virginia's patents cover a diverse set of patent classes. With the exception of synthetic resins and natural rubbers, no patent class has a concentration of more than 4 percent of the state's total patents (Table 16).

Table 16: West Virginia's Top Patent Classes, 2000–April 2006

Top Patent Classes	Number of Patents	% of Total West Virginia Patents
Synthetic resins or natural rubbers	236	17.2
Stock material or miscellaneous articles	55	4.0
Catalyst, solid sorbent, or support therefore: product or process of making	37	2.7
Wells	36	2.6
Organic compounds	25	1.8
Boring or penetrating the earth	22	1.6
Compositions	22	1.6
Drug, bio-affecting and body treating compositions	21	1.5

Source: Delphion Patent Database, with Battelle calculations.

The patent data reveal the heritage of West Virginia's chemical and energy industries. Union Carbide Chemicals and Plastics Technology Corporation, a wholly owned subsidiary of Dow Chemicals, was the largest generator of patents in West Virginia, with 115 patents between 2000 and April 2006. Bayer Corporation, the German chemical and pharmaceutical company, was assigned 83 patents; Univation Technologies, a joint venture of Exxon Mobil and Dow Chemicals, was assigned 78 patents. Table 17 lists West Virginia organizations assigned at least 10 patents between 2000 and April 2006.

Table 17: Assignees with >10 West Virginia Patents, 2000–April 2006

Institution/Organization	Number of Patents
Union Carbide Chemicals and Plastics Technology Corporation (Subsidiary of Dow)	115
Bayer Corporation USA	83
Univation Technologies, LLC	78
E. I. du Pont de Nemours and Company	61
CDX Gas, LLC	48
Individuals	45
General Electric Company	28
Ames True Temper, Inc.	26
West Virginia University	24
Walker Systems, Inc.-West Virginia	20
Crompton Corporation	17
Touchstone Research Laboratory, Ltd.	14
Marathon Ashland Petroleum, LLC	13
Ashland, Inc.	12
Bayer AG	11
Inco Alloys International, Inc.	10
Mack Trucks, Inc.	10
The Louis Berkman Company	10
United States Department of Energy	10

Source: Delphion Patent Database, with Battelle calculations.

[29] Science and Technology State Profiles: 2003–2004, NSF 06-0314, May 2006 at www.nsf.gov/statistics/nsf06314.

Cluster Analysis

To develop a deeper quantitative assessment of West Virginia's research strengths and key themes that transcend institutional, research, and innovation boundaries, Battelle conducted a specialized cluster analysis using data on recent research grants awarded to organizations in the state, as well as patents assigned to West Virginia companies, institutions, or individuals.

Using a Battelle-developed data-mining/text-clustering tool, OmniViz™, the team examined how grants and patents relate to one another based on the actual research or innovation described within the textual information collected. In some instances, a thematic strength may revolve around a topic (e.g., cancer, polymers, energy), linking together a variety of research approaches, or around a technique (e.g., nanotechnology), focusing on the development and application of such techniques toward a host of research domains. Battelle has applied this tool in other state and regional studies and in its own efforts to identify technology focus areas within its overall research activities across its many offices and laboratories.

Battelle attempted to include all federal research grants (including grant title, grant abstract, and key words) from FY 2000 to date. However, public access to research grants from key agencies such as the DoD, DOE, and NASA is unavailable. Some of these grant records were available through the RAND Corporation's Research and Development in the United States (RaDiUS) database. However, due to data time lags, only data from FY 2000 to FY 2004 are available. Furthermore, due to the secure nature of much of the research funded through these departments, many specific awards are not reported, and many are reported but with little useful textual information for OmniViz™ to analyze. A total of 1,289 research grant records were included in the cluster analysis.

Patent records were obtained from the Delphion patent analysis database. A total of 1,371 patent records, including patents from January 1, 2000, through April 2006, were included in the analysis.

In the process of clustering the significant amount of textual data included in this analysis, some textual information did not purposefully "cluster" into one of the key themes, yet was "forced" into a cluster because of the numeric algorithms used by the tool. In general, these records cluster into a few invalid clusters (based on some random collection of terms) or latch onto one of the key terms, again owing to some random similarity in meaningless terms. These data artifacts/invalid clusters ultimately fall out of the analysis process.

OmniViz™ establishes the clusters based on the specific dataset characteristics and key parameters developed by the analysts. The Battelle team analyzes the cluster construct and the content of the individual grant awards or patents to interpret and name stand-alone clusters or to group a set of closely aligned clusters into "metaclusters." While these metaclusters are often the key themes of the dataset under analysis, it is possible to have key themes made up of a single cluster consisting of a large number of closely aligned individual grants or patents.

Overall, 49 individual clusters were identified through use of OmniViz™. A significant number of records dropped out of the analysis as artifacts. The 49 valid clusters were grouped into 17 metaclusters, which are listed in Table 18. Fields with large numbers of grants and/or patents are as follows:

- Cellular and molecular biology
- Chemicals and catalysts

- Composites and advanced materials
- Drugs, diagnostics, and therapeutics
- Instruments, controls, and electronics
- Polymers.

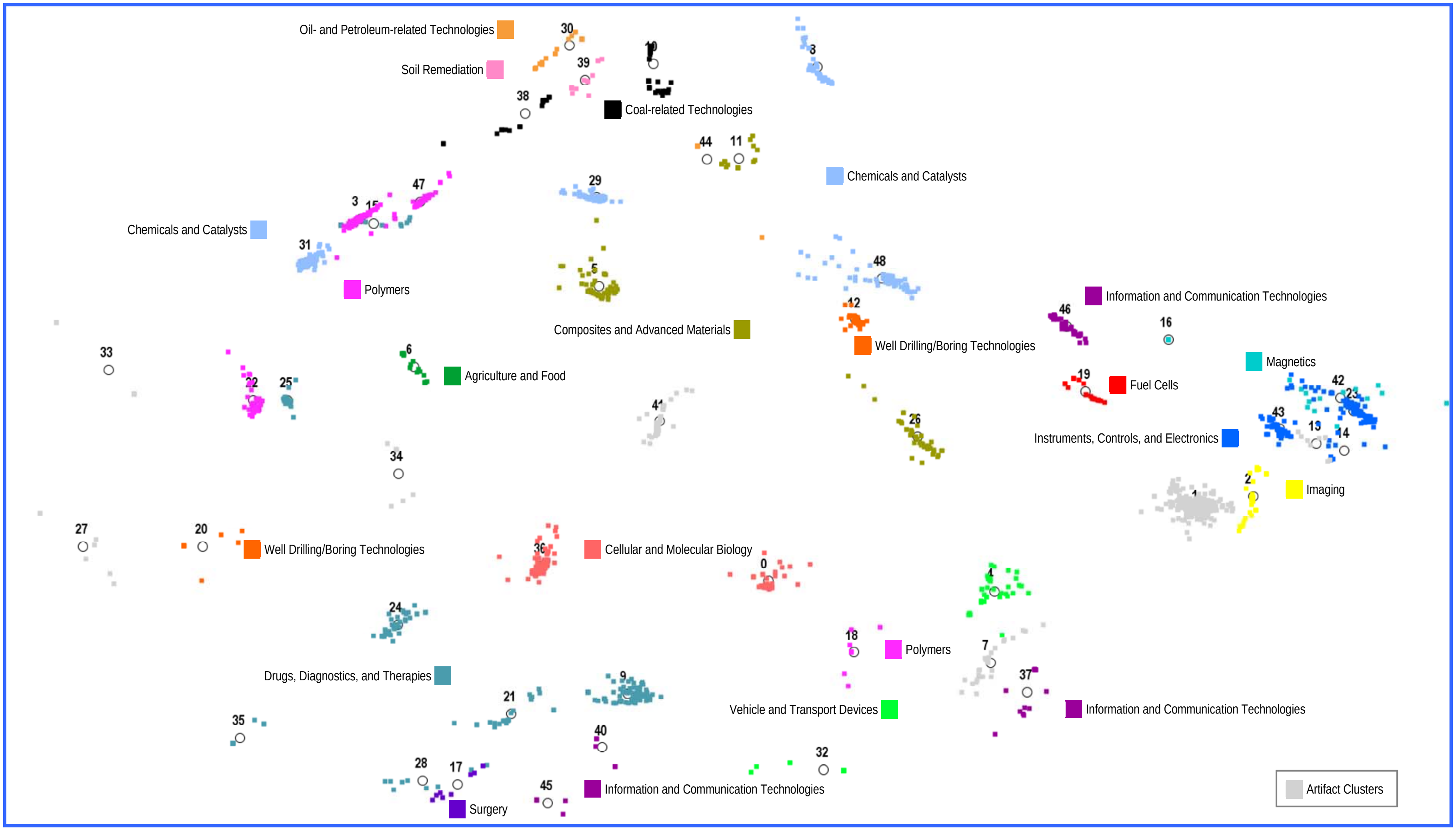
These fields correspond to those areas in West Virginia where strength in technology R&D is evident.

Table 18: West Virginia Metaclusters, 2000–2006

Metacluster	Individual Clusters in Metacluster	Total Records	Grants	Patents
Agriculture and Food	1	17	13	4
Cellular and Molecular Biology	2	192	162	30
Chemicals and Catalysts	3	463	93	370
Coal-Related Technologies	2	85	81	4
Composites and Advanced Materials	3	124	39	85
Drugs, Diagnostics, and Therapies	7	212	193	19
Fuel Cells	1	24	20	4
Imaging	2	31	22	9
Information and Communication Technologies	4	67	49	18
Instruments, Controls, and Electronics	3	151	29	122
Magnetics	2	17	13	4
Oil and Petroleum-Related Technologies	2	39	36	3
Polymers	4	186	16	170
Soil Remediation	1	13	12	1
Surgery	1	9	6	3
Vehicles and Transport Devices	2	48	11	37
Well Drilling/Boring Technologies	2	69	17	52

Figure 16 presents the results of the cluster analysis as a "map" of clusters and metaclusters. The map illustrates the size and density of each cluster as well as the "relatedness" of clusters. Clusters nearer one another on the map are typically more closely related by subject. Examination of the clusters reveals groupings that may be categorized in the following areas: energy and energy-related technology, materials and chemicals, information technology and electronics, and biosciences and life sciences.

Figure 16: West Virginia Grant and Patent Cluster Analysis



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Summary of Quantitative Strengths

Table 19 summarizes the key areas of R&D strength in West Virginia as identified by the quantitative data in research funding, publications, and patents data. West Virginia does have the opportunity to build upon strengths in engineering and physical sciences, and also in multiple bioscience fields.

Table 19: West Virginia's Areas of Research Strengths Identified Through Quantitative Analysis

Areas Focused in Engineering and Physical Sciences				
Competency Area	**Publications/Citations Strength (ISI Data)**	**OmniViz™ Clusters**	**Major Funded Centers or Institutes**	**Notes**
Energy and Energy-Related Technology	Spread across multiple science and engineering disciplines. No specific ISI category Federal funding data show West Virginia more focused on engineering R&D than the nation as a whole	• Coal-related technologies • Oil- and petroleum-related technologies • Well drilling and boring technology • Fuel cells • Vehicles and transport devices	• NETL • National Research Center for Coal and Energy • Advanced Power and Electricity Research Center • Research Center for Alternative Fuels, Engines and Emissions • West Virginia Industries of the Future	Major fossil fuel emphasis: ➢ Resources ➢ Technology ➢ Efficiency ➢ Environment NETL with 407 full-time employees (FTEs) and $32 million local research budget ($259 million total)
Materials and Materials Science	• Applied physics/materials science • Polymer science	• Composites and advanced materials • Polymers • Chemicals and catalysts		Broad range of research focus areas—ranging from paving materials to nanomaterials 85 patents
Chemicals and Chemical Engineering	• Chemical engineering • Polymer science	• Chemicals and catalysts • Polymers	• Mid-Atlantic Technology Research and Innovation Center	Strong industry R&D in chemicals and catalysts with 370 patents, and in polymers with 170 patents
Computer Science and Associated Electronics Engineering		• Information and communication technologies • Instruments, controls, and electronics	• WVNano • Center for Identification Technology Research	Major emphasis on identification technology, sensors, and nanotechnology 122 patents in instruments, controls, and electronics

Table 19: West Virginia's Areas of Research Strengths Identified Through Quantitative Analysis (continued)

Areas Focused in Biosciences				
Competency Area	**Publications/ Citations Strength (ISI Data)**	**OmniViz™ Clusters**	**Major Funded Centers or Institutes**	**Notes**
Environmental Science and Ecology	• Environment/Ecology • <50 papers, but influential in environmental engineering and energy; environmental medicine; environmental studies, geography and development	• Soil remediation	• NETL • WVU National Environmental Services Center • National Research Center for Coal and Energy • Research Center for Alternative Fuels, Engines and Emissions • West Virginia Water Research Institute	Major cross-disciplinary strengths Strong emphasis on fossil energy pollution control and environmental remediation technology
Neurology and Neurosciences	• Neurology • Neuroscience and behavior	• Drugs, diagnostics, and therapies • Cellular and molecular biology	• Sensory Neuroscience Research Center • BRNI • WVU Eye Institute	Long-term WVU strength, reinforced with recent investment in infrastructure and talent
Cancer	• Oncogenesis and cancer research • Pharmacology and toxicology	• Drugs, diagnostics, and therapies • Cellular and molecular biology	• WVU Mary Babb Randolph Cancer Center (signaling networks, tumor microenvironment, molecular therapeutics) • MU Cancer Biology Research Cluster • WVNano—signal detection/biomarkers	Multi-institutional capabilities stretching across WVU, MU, and WJU
Pharmacology and Toxicology	• Pharmacology and toxicology	• Drugs, diagnostics, and therapies • Cellular and molecular biology		Multi-institutional capabilities stretching across WVU and MU
Imaging	• Radiology, nuclear medicine, and imaging	• Imaging	• WVU Center for Advanced Imaging • WVU Virtual Environments Laboratory	MU developing visualization and imaging capabilities

Table 19: West Virginia's Areas of Research Strengths Identified Through Quantitative Analysis (continued)

Areas Focused in Biosciences (continued)				
Competency Area	**Publications/Citations Strength (ISI Data)**	**OmniViz™ Clusters**	**Major Funded Centers or Institutes**	**Notes**
Public Health and Occupational Health/Safety	• Public health and healthcare sciences		• NIOSH Division of Safety Research, Division of Respiratory Disease Studies, Health Effects Laboratory Division • WVU Institute of Occupational and Environmental Health	NIOSH major presence with 369 FTEs and $36.1 million. R&D focus at WVU
Psychology	• Psychology			Multi-institutional strengths at WVU and MU
Plant Sciences	• Plant sciences	• Agriculture and food • Cellular and molecular biology		

Qualitative Assessment of West Virginia's Technology R&D Base: Interview and Fieldwork Findings

The quantitative analysis provides a context for understanding where West Virginia's core competencies in science and technology research are focused. To further investigate these fields and deepen the team's understanding of the research core competencies in West Virginia, Battelle conducted extensive interviews with university administrators, faculty, scientists, clinicians, industry executives, federal laboratory personnel, and development agencies in the state. These interviews were essential in developing an understanding of how the data on publications, patents, and grant awards translate into on-the-ground focus areas in West Virginia.

In total, telephone interviews and face-to-face interviews individually or in small group sessions were conducted with more than 60 individuals, including senior academic research scientists and faculty at WVU, MU, and WJU and administrative and scientific personnel at federal laboratory operations in the state. These interviews and interviews with technology companies and associated industry promotion and economic development groups contributed to the identification and analysis of core competencies.

The interviews partly confirmed West Virginia's research strengths identified in the quantitative analysis. They also highlighted several new and emerging areas of R&D and some key theme areas that were not readily apparent within the quantitative datasets. One challenge in using quantitative data is the rapid rate of change in the scientific enterprise. Peer review systems—whether used for federal grant awards, citation analysis, or in reputation rankings—tend to lag emerging new fields of inquiry and may fail to recognize the contributions of younger and new scientific talent. Therefore, one objective of the qualitative interviews was to capture emerging areas, faculty, and fields of inquiry at each of the subject institutions.

The core content of the field interviews was synthesized, and key areas of research strength and expertise were identified. These qualitative interviews and the quantitative research go hand-in-hand in determining core competencies and identifying the following:

- Where West Virginia is heading in terms of building upon and leveraging its core technology strengths and developing and enhancing new and emerging areas of science and technology focus
- What the current pipeline of science and technology R&D activity is within academic research institutions and federal laboratories in West Virginia
- Which areas of science and technology R&D are generating patents and IP that can lead to commercial opportunities for West Virginia.

The field interviews provide information relevant to each of these questions; but, they are most important in providing an in-depth understanding of current and emerging R&D strengths and opportunities.

Based on the interviews, and in reference to the quantitative analysis, findings were organized into two basic levels:

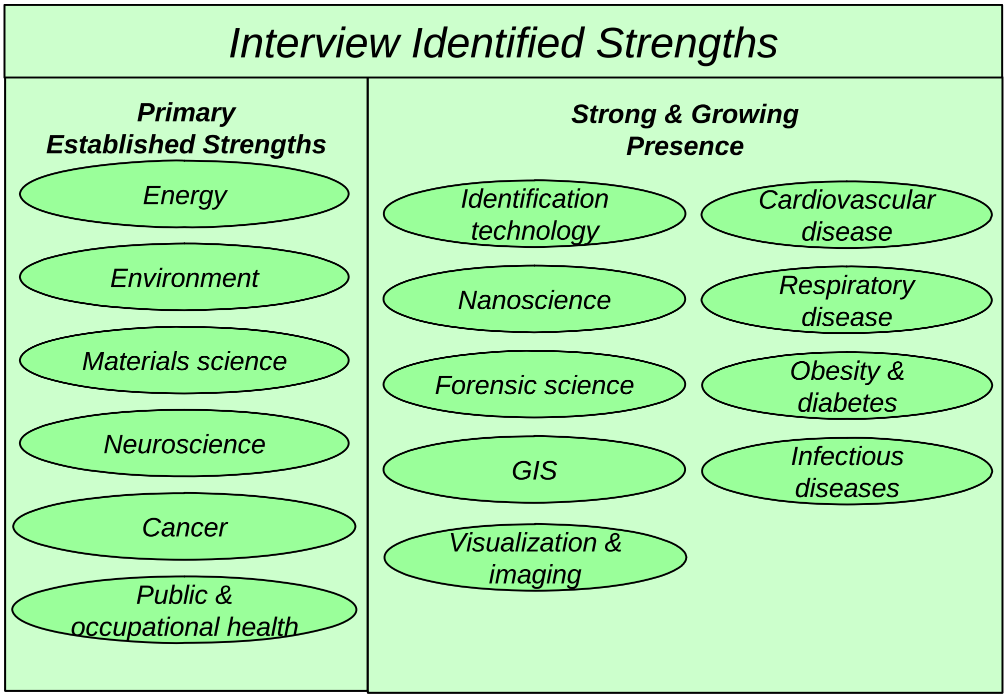
Primary Established Strengths in which West Virginia has considerable presence through at least two of the following:

- A significant number of well-funded researchers, scientists, and/or clinician scientists working in basic or applied R&D
- Applied science R&D assisting critically important current and/or emerging commercial sectors
- A number of commercial enterprises with R&D or production facilities working on the delivery of products or services
- Recognized clinical expertise (in biomedical fields).

Strong and Growing Presence in which West Virginia has demonstrated strengths that are more focused or one dimensional; have lower levels of research activity, clinical expertise, or commercial enterprises; or are more niche focused. In many instances, these include research areas required to support other areas of strength or to form platforms for economic development from science and technology. As such, these are highly important strengths to continue building.

Based on these general parameters, the project team identified research competency areas from the qualitative interviews as shown in Figure 17.

Figure 17: West Virginia's Research Strengths Identified in Interviews



It should be recognized that many of these strengths are supported by considerable investment and expertise contained within multiple cross-cutting areas of science and technology. Strengths in basic science and engineering disciplines, and the underlying science and technology R&D infrastructure in the state, must be maintained and invested in for core competencies to be sustained and leveraged.

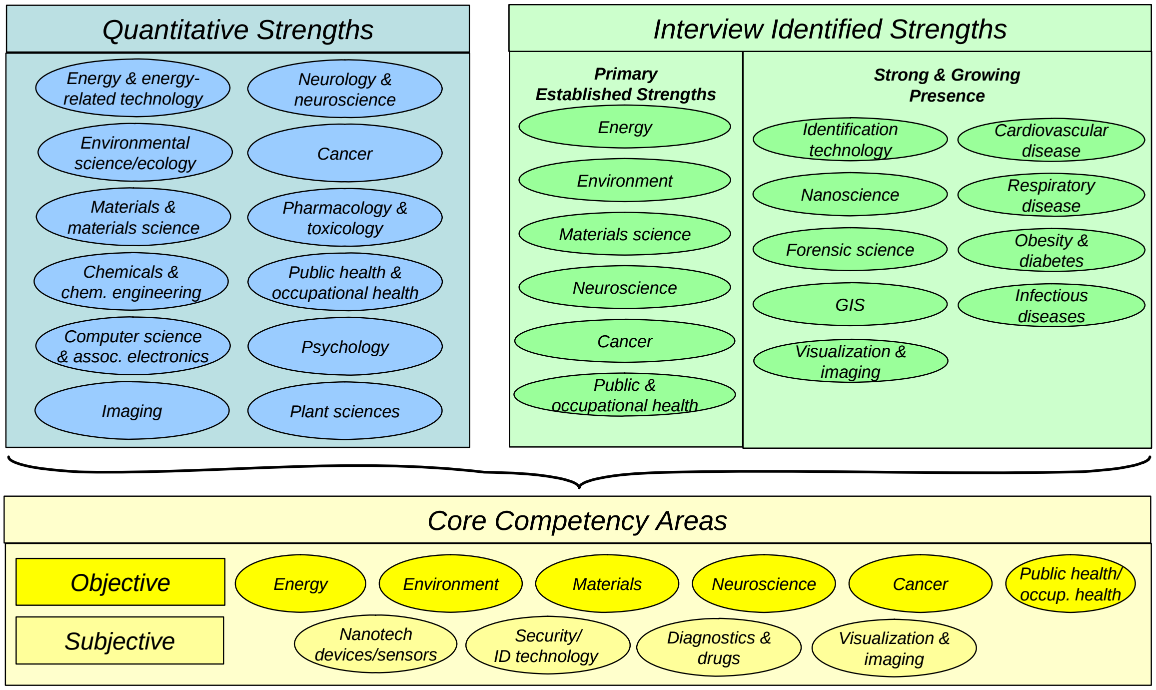
It should also be noted that, in modern science and technology fields, an area of focus seldom stands on its own. Rather, just as organisms form complex systems, modern science itself should be viewed as a complex system of interrelated disciplines and areas of study that support and assist in the advancement of one another. For this reason, federal funding organizations are increasingly focusing their grant-making attention on interdisciplinary institutes, centers, and research teams. As such, the formation of focused interdisciplinary teams, centers, and institutes should be recognized as imperative for success in accessing large-scale federal grant funding in the future.

The links between and across strength areas are critical to the emergence of science and technology core competencies for West Virginia. As in any system, a change in one parameters (strength area) is likely to affect the others. For example, a center for the support of nanosensor development may increase the attention of various medical, engineering, and environmental subdisciplines on applications for advanced nanosensors in their work. Likewise, a center for the study of novel drug delivery methods might stimulate interdisciplinary teams to form around applications to cancer, cardiovascular disease, or neuro-degenerative diseases.

From Strengths to Core Competencies

Referring to both the quantitative strength data and information derived from the interviews, Battelle identified general science and technology R&D core competencies in the state. Figure 18 provides a crosswalk of the quantitative and qualitative findings and identifies the research core competencies clearly suggested by these information sources.

Figure18: West Virginia's Research Core Competencies



The "objective" core competencies are those whose competency was sustained by information gathered in both the quantitative analysis and qualitative interviews. The project team determined the "subjective" competencies by examining the details of major R&D initiatives, cross-disciplinary research areas, and emerging areas that together form a logical technology core competency focus. Each core competency is described in detail in Appendix A.

These core competencies are the building blocks with which West Virginia's innovation-based economy may be built. Given these core competencies, the Battelle team proposed "technology platforms" that offer a competitive niche for West Virginia. The recommended platforms and the research core competencies to leverage in building them are discussed in detail in the following section.

Technology Platforms, Products, and Market Niches for West Virginia

> **Criteria for Selecting Technology Platforms for Development**
>
> - Builds on existing strengths
> - Has a base of related emerging or established commercial activity
> - Provides opportunity to leverage state's comparative advantages
> - Has significant product market potential
> - Links or reinforces other strengths and core competencies

The purpose of identifying a state's research strengths and core competencies is to identify strategic areas of focus that offer the greatest opportunity for near-term development—termed "technology platforms" by Battelle.

Technology platforms serve as a bridge between research core competencies and their use in commercial applications and products. As such, platforms are highly translational—working to move ideas and innovations from basic science discoveries to applied technologies and practices.

The technology platform process can be understood through a systems approach in which innovations flow from core competencies resident in a state's research institutions, via the platforms, to commercial products, which then find their way into markets. These technology platforms are intended to be robust and evergreen and to integrate several core competencies to produce a continuous flow of innovative, and perhaps disruptive, technology or products. Platforms also serve as a forum for building strong interactions and relationships between academic researchers and their counterparts in industry.

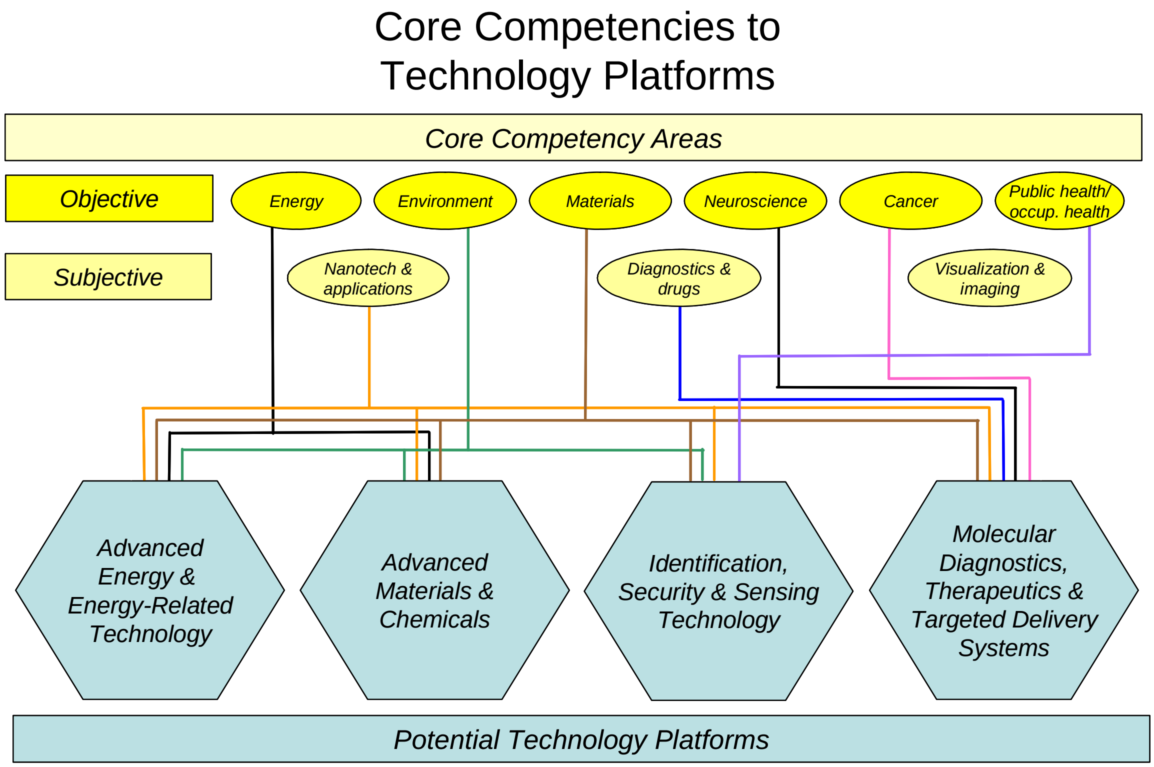
The areas of greatest opportunity for developing technology platforms are those in which a state has the following:

- Existing research strengths
- Bases of commercial activity emerging or established within the state with genuine opportunity to create a base in the near future
- Distinct opportunities to leverage the state's comparative advantages to create competitive marketplace advantages
- Significant product market potential
- Links to, or reinforcements of, other science and technology strengths and core research competencies, thereby helping to enhance other fields as a platform expands.

Translating West Virginia Core Competencies Into Technology Platforms

As discussed in previous chapters, West Virginia has an existing base of science and technology R&D core competencies. Translating R&D core competencies into technology-based economic development platforms requires understanding the cross-disciplinary relationships, and the existing connections, upon which broad-based and robust platforms can be built. Figure 19 illustrates the interrelationships between each R&D core competency and the individual development platforms that Battelle recommends based upon these competencies.

Figure 19: Proposed Technology Platforms for West Virginia



It can be seen from Figure 19 that the nine core competency areas link to the following four West Virginia–specific technology platforms:

- **Advanced Energy and Energy-Related Technology**
- **Advanced Materials and Chemicals**
- **Identification, Security, and Sensing Technology**
- **Molecular Diagnostics, Therapeutics, and Targeted Delivery Systems.**

The technology platforms represent the base from which a significant R&D, business base, and technology-driven economy may be built. They each specifically draw upon West Virginia's institutional expertise in multiple fields, since it is multidisciplinary research that is increasingly gaining importance in driving new study areas, technologies, and commercializable innovations and discoveries. The assembly of multidisciplinary platforms is also likely to increase the opportunity for winning federal agency grant awards.

Each platform is discussed in a narrative that follows. Each narrative includes a figure showing the specific linkages between the quantitatively based and qualitatively based core competency disciplines and recommended platforms and opportunity areas. The figures illustrate how these platforms are reinforced by the R&D talent across a wide range of disciplines within West Virginia.

ADVANCED ENERGY AND ENERGY-RELATED TECHNOLOGY PLATFORM

For generations, the nation's demand for energy has benefited West Virginia. Extraction of the state's fossil energy resources (most notably coal and natural gas) forms a basic industry that drives a major component of West Virginia's economy. The coal industry alone generates more than $3.5 billion annually in West Virginia's GSP and directly accounts for more than 40,000 jobs and has a $2 billion annual payroll.[30] Within West Virginia, coal drives a vertically integrated energy industry, with 99 percent of West Virginia's electricity generated by coal-fired generating facilities. Taxes paid by this integrated coal-based energy sector account for two-thirds of business taxes paid in the state. Currently, the state produces far more coal than needed for in-state uses; it ranks as the leading state in the nation in terms of coal exports, with more than 50 million tons shipped to 23 countries annually.

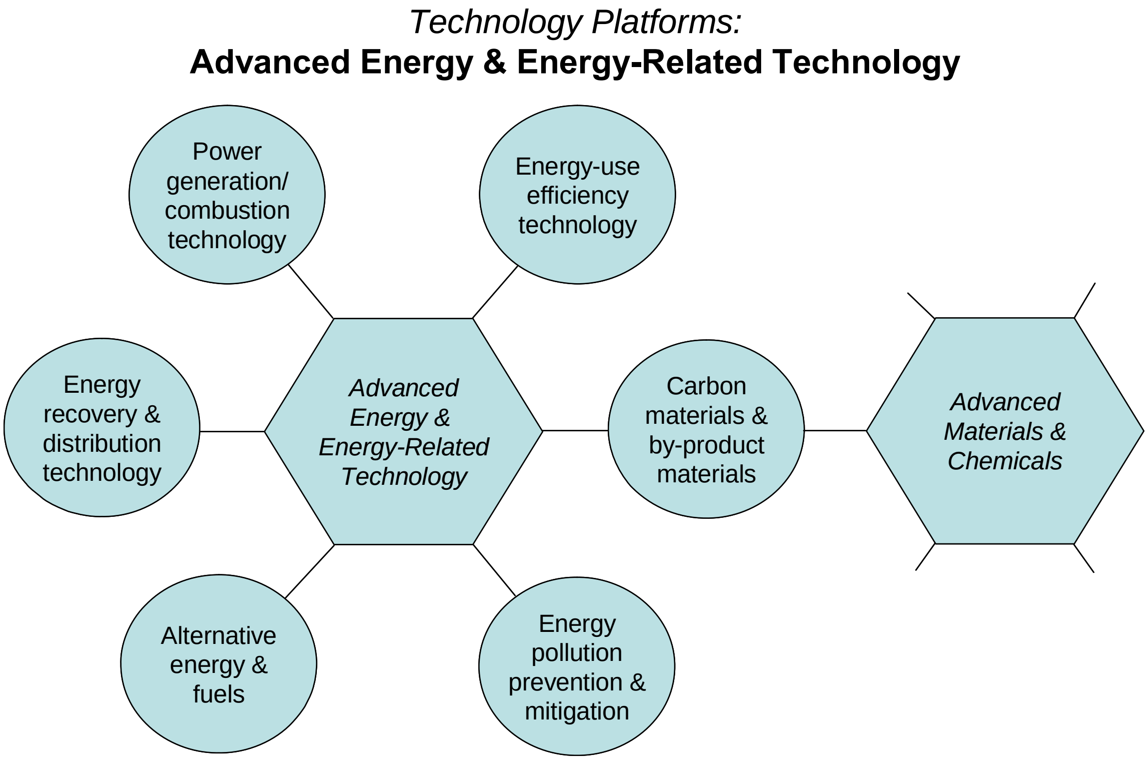
West Virginia oil and natural gas reserves are also significant. The state is the only net exporter of natural gas east of the Mississippi and, according to the West Virginia Geological and Economic Survey, the state currently contains approximately 40,500 natural gas wells producing 191.6 billion cubic feet of gas annually and 7,500 oil wells producing 1.9 million barrels of crude.[31]

Against this background of fossil fuel extraction and utilization, it is not surprising that West Virginia is also home to a substantial base of energy R&D activity. The state's research universities, especially WVU, have major R&D programs focused on the energy sector in terms of engineering, basic physical sciences, earth science, and business and economic analysis. West Virginia is also home to a major DoD laboratory dedicated to fossil fuel R&D—the NETL. Together, the NETL and university R&D base provides West Virginia with the basic and applied R&D expertise required to drive the development of the next generation of fossil fuel extraction, processing, utilization, transmission, and pollution control technologies. These R&D organizations are, however, also looking beyond fossil fuels into other advanced energy systems, such as fuel cells and renewable energy applications, and are also focused on the development of engines, combustion systems, and other technologies for maximized efficiency in converting energy to power.

The alignment of West Virginia fossil fuel resources, with advanced energy R&D in the state and growing domestic and global demand for energy, provides West Virginia with an opportunity to **leverage energy as a platform for advanced technology development and economic progress**. Chief among the goals of such a platform should be to increase the value-added economic activity based on energy resources—developing high-value liquid fuels from carbon products, carbon-based chemicals, and advanced technologies for high-efficiency combustion, fuel conversion, pollution control, and energy transmission.[32] Figure 20 illustrates opportunity areas for technology development from the recommended advanced energy and energy-related technology platform and also the cross-platform connectivity between the advanced energy platform and the advanced materials and chemicals platform.

[30] "West Virginia Coal Mining Facts." West Virginia Office of Miners' Health, Safety and Training. http://www.wvminesafety.org/wvcoalfacts.htm.
[31] West Virginia Development Office. http://www.wvdo.org/business/ng_oil.html.
[32] An illustration of increased value-capture is provided in Figure 28.

Figure 20: Overview of Advanced Energy and Related-Energy Technology Platform



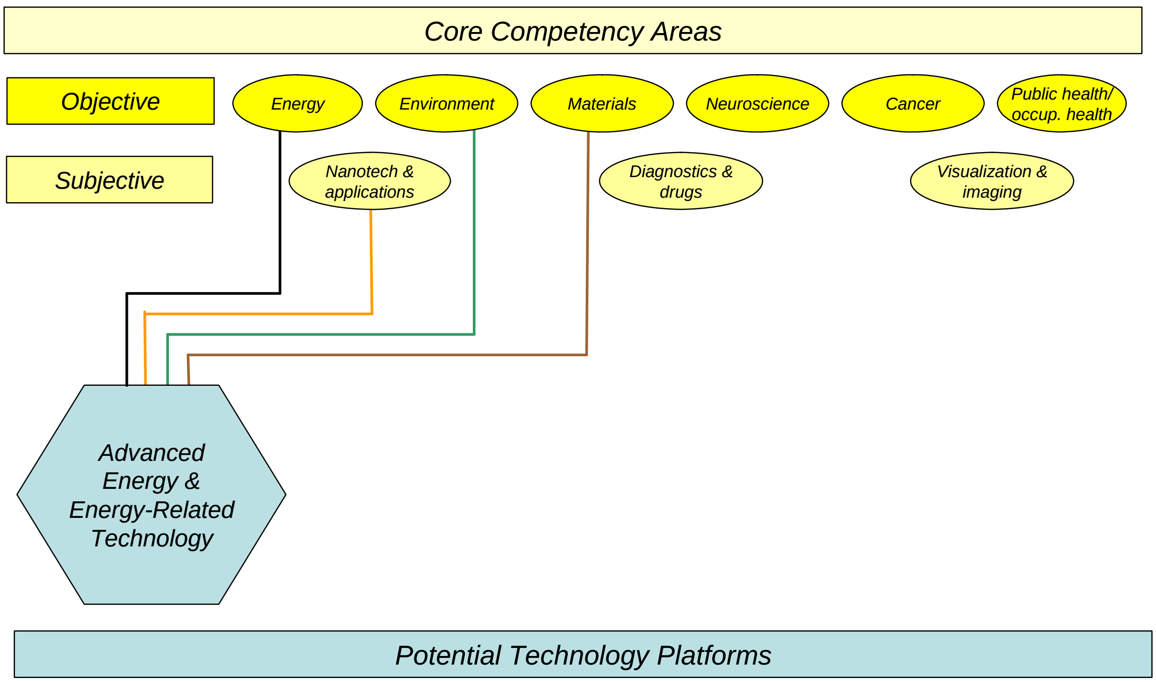
Assessing West Virginia's energy and related technology R&D demonstrates that the advanced energy platform presents development opportunities along multiple technology paths, including the following:

- **Power Generation/Combustion Technology**—Developing advanced combustion systems, generators, engines, and related technologies.
- **Energy-Use Efficiency Technology**—Producing technology that increases the fuel-use efficiency of energy conversion and power generation equipment, engines, and related devices (such as transmissions).
- **Carbon Materials and By-Product Materials**—Advancing technology to convert fossil carbon resources into value-added carbon products, chemicals, liquid fuels, and gases.
- **Energy Pollution Prevention and Mitigation**—Developing advanced technologies for reducing or eliminating polluting emissions from energy production and consumption activities.
- **Alternative Energy and Fuels**—Producing advanced and alternative fuel and energy generation technologies such as fuel cells.
- **Energy Recovery and Distribution Technology**—Advancing R&D to enhance the recovery of valuable fossil resources from reserves and tailings and technologies for improving energy distribution efficiency, reliability, and security.

These categories represent key areas of opportunity for technology-development from this platform. It should be noted, however, that the R&D expertise contained within the federal laboratory/university R&D complex in West Virginia is so broad that additional opportunities for technology development will no doubt present themselves. NETL has deep expertise in computational modeling and simulation that may well lead to commercializable technology development. Likewise, WVU maintains programs dedicated to servicing the research, training, and certification needs of industry in energy and transportation that may be leveraged for further development gain.

Figure 21 illustrates multiple core competencies identified during the performance of this analysis that provide direct or indirect support to the advanced energy and energy-related technology platform. In addition to the direct energy R&D core competencies, state R&D strengths in environmental science and associated technologies, materials and chemicals, and nanotechnology are likely to provide valuable development support for the overall platform.

Figure 21: Relationship of Core Competencies to the Advanced Energy and Energy-Related Technology Platform



ADVANCED MATERIALS AND CHEMICALS

In addition to energy production, West Virginia has a strong track record in developing and producing chemicals and materials. The Kanawha Valley has been home to intensive chemical industry operations for more than a century, and the Ohio Valley in and around Parkersburg has a similar track record in the chemicals sector. In materials, West Virginia has also enjoyed a strong presence in primary metals production and manufacturing operations, notably in the steel sector, but also in other metals and materials. Wood, a biorenewable material, also represents a significant economic resource for the state. In 2004, six of the top 10 West Virginia manufacturing sectors were chemicals and materials related, including the following:

- Chemicals—$1.6 billion
- Wood—$642 million
- Primary Metals—$556 million
- Fabricated Metals—$463 million
- Nonmetallic Minerals—$328 million
- Plastics and Rubber—$286 million.

Combined, these six materials-related manufacturing sectors are responsible for over 70 percent of all West Virginia manufacturing output, demonstrating the importance of chemicals and materials to the West Virginia economy.

Clearly, maintaining the economic viability of the materials sectors is highly important to the economic sustainability of the state. R&D within industry, academe, and other research institutions within the state play an important role in securing a future for the West Virginia materials sectors. From an industry perspective, patent data illustrate the considerable volume of industry R&D taking place in these sectors within the state. The OmniViz™ cluster analysis recorded 625 patents issued between January 1, 2000, and April 2006 in “chemicals and catalysts,” “composites and advanced materials,” and “polymers.”

Within the R&D sector in West Virginia, interviews identified multiple areas of strengths in advanced materials and chemical technologies. R&D focus areas identified in the state show considerable attention being paid to advancing work in high-value materials such as the following:

- Electronics, semiconductor, and sensor materials
- Advanced composite materials
- Advanced polymers
- Catalysts and catalytic materials
- Products from West Virginia carbon, including carbon foams, anodes, and metal-casting materials
- Value-added wood products
- Nano and nanobio materials.

It is clear that the combination of West Virginia’s existing industry base in materials and chemicals, coupled with significant R&D expertise relevant to the next generation of advanced materials and chemicals, provides the state with an opportunity for further development through an advanced materials and chemicals technology platform.

Figure 22 illustrates opportunity areas for technology development from the recommended advanced materials and chemicals technology platform and also the cross-platform connectivity between the platform and other recommended platforms.

Figure 22: Advanced Materials and Chemicals Technology Platform

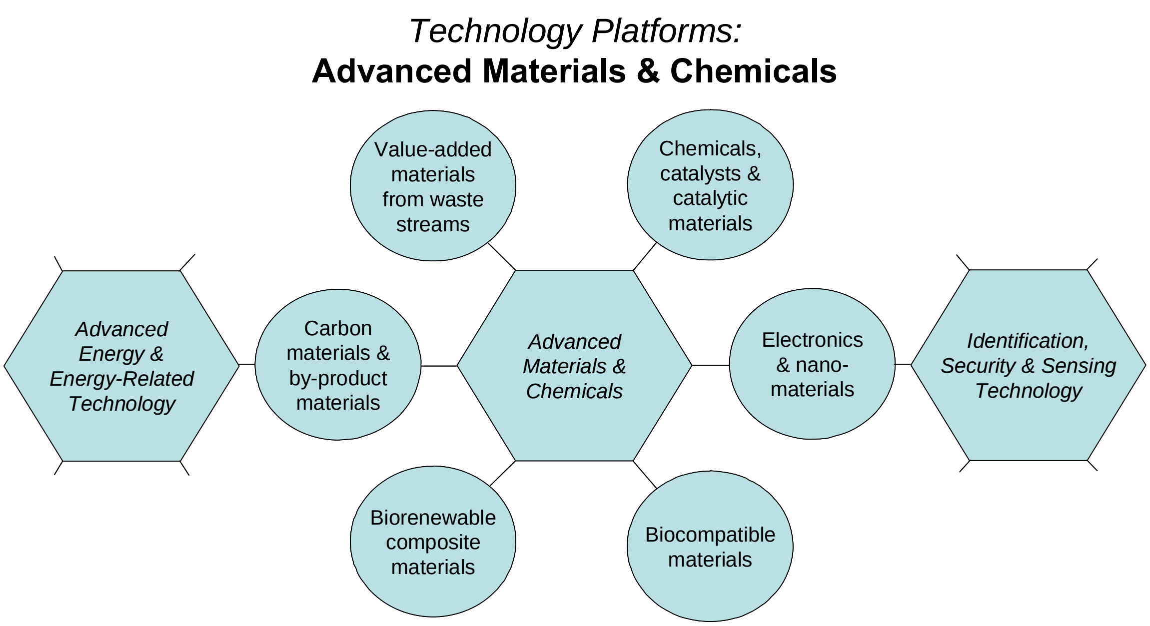
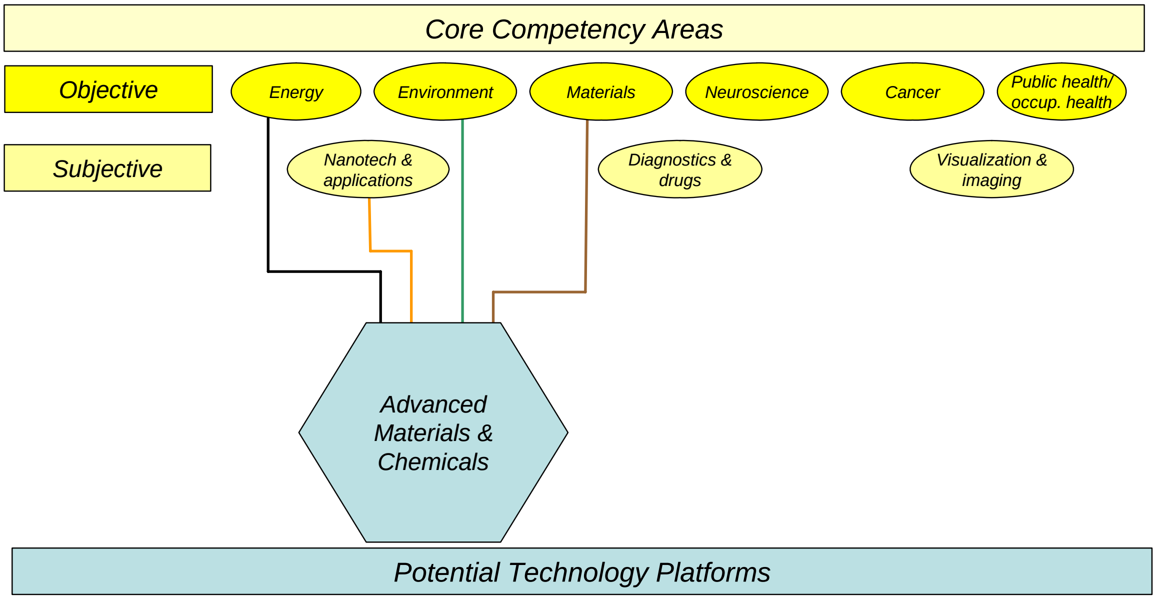


Figure 23 illustrates multiple core competencies identified during the performance of this analysis that provide direct or indirect support to the advanced materials and chemicals technology platform.

Figure 23: Relationship Between Core Competencies and Advanced Materials and Chemicals Technology Platform



IDENTIFICATION, SECURITY, AND SENSING TECHNOLOGY PLATFORM

The need for advanced security technologies based on the accurate identification of an individual has perhaps never been greater than it is today. National security concerns, in combination with the rapid growth of "identity theft" as a 21st century crime, are placing a strong imperative on the development of technologies that use biometrics, advanced sensors, and other technologies to certify the true identity of an individual. The need for such advanced technology is critically important for many applications, including, for example, banking and finance, health care and health insurance, government-issued identification such as driver's licenses and visas, and secure access to sensitive facilities and government installations. The market for such technologies will be extremely large—just one recent Presidential directive, for example, calls for all federal employees and contractors to have biometric ID cards by the end of 2007 (a mandate covering over 19 million persons). The proposed Real ID Act will require all U.S. states to have biometric-enabled interagency and interstate identification systems and databases in place to assure documents are issued to the appropriate individual.

During this time of substantial market opportunity, West Virginia has developed the following significant assets, close to one another in north central West Virginia along the I-79 corridor, that together can form the basis of a very robust platform focused on identification technology, security technology, and advanced sensing technology:

- **The National Biometric Security Project (NBSP)**—A nonprofit agency formed to provide unbiased service and support to government and the private sector in acquiring and applying biometric technology. The NBSP is developing standards and providing testing, certification, research, training, and education services in biometric technology and applications. The NBSP is also working to secure contracts that would make it the central secure data repository for key federal, state, and private sector biometric data.
- **The DoD "Biometrics Fusion Center"**—Housing the DoD's biometric operations in technology evaluation and testing, biometrics knowledgebase and information repository, advice and support for

DoD agencies and units, and the gateway for collaboration in biometrics between the DoD and academic research institutions.

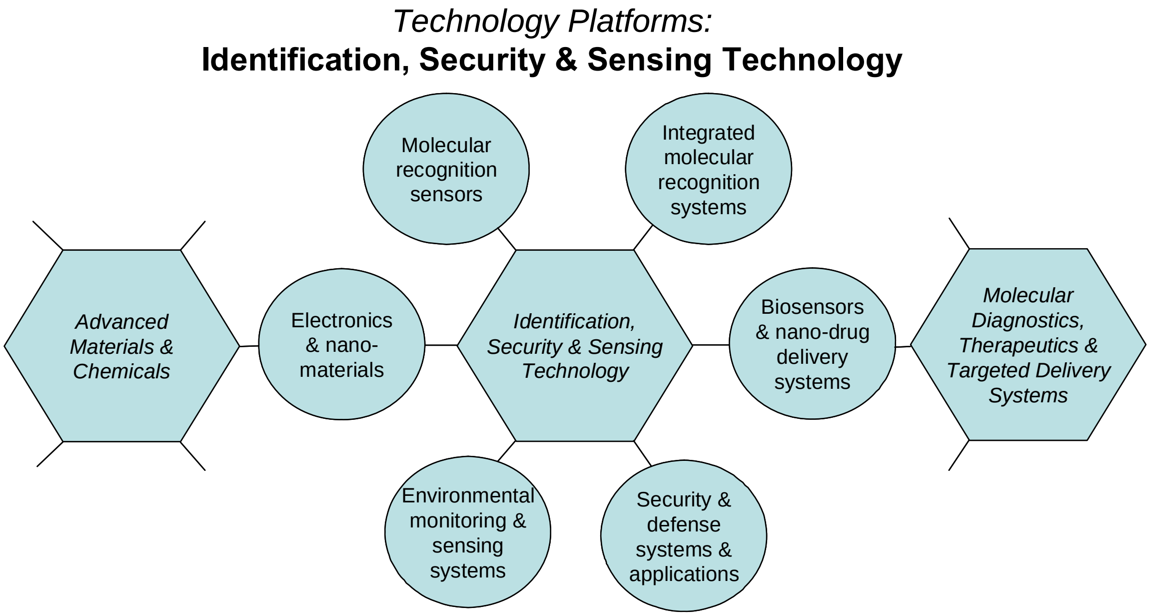
- **The FBI CJIS in West Virginia**—Hosting the National Crime Information Center, including its Brady Act gun-check headquarters, its Uniform Crime Reports data center, and its Integrated Automated Fingerprint Identification System. Thus, law enforcement agencies nationwide refer to the West Virginia FBI operation for identification services.
- **The Center for Identification Technology Research (CITeR) at WVU**—The first NSF Industry/University Cooperative Research Center (IUCRC) focusing on serving its membership in the rapidly growing area of biometric identification technology. CITeR advances the performance of biometric systems through cross-cutting research of new enabling technologies, provides interdisciplinary training of scientists and engineers in biometrics, and facilitates the transfer of new biometrics technology to the private and government sectors through its membership. CITeR incorporates the Biometric Knowledge Center at WVU with the aim of fostering interdisciplinary collaborations in biometrics research.
- **The Forensic Science Initiative at WVU**—Providing research and resources to the nation's forensic science laboratories and considered to be the largest and broadest academic research effort in forensic sciences in the nation. Working closely with WVU's nationally recognized Forensic and Investigative Sciences program, the Forensic Science Initiative provides access for students and others in forensics training to the latest tools and technologies of forensic science.
- **WVNano Initiative at WVU and MU**—A statewide initiative supported through an NSF EPSCoR Research Infrastructure Improvement grant to the State of West Virginia. For security and biometrics, the initiative has a major focus on discoveries in materials, devices, and biomolecular systems that will advance molecular recognition technology for security, health, environment, and energy applications.

The I-79 Council is currently engaged in a Biometrics Initiative with the goal of bringing together these key assets to form a consortium of R&D and associated entities that can be greater than the sum of its parts—assuring West Virginia secures a major leadership position in the emerging identification, sensing, and associated security applications fields.

Beyond the assets in the I-79 corridor, there are also assets at MU in Huntington, including the **MU Forensic Science Center**. The center was created in 1994 and offers a master's degree in forensic sciences. It also conducts research in the areas of deoxyribonucleic acid analysis, forensic chemistry, computer forensics, and microbial forensics. The Forensic Science Center provides a number of DNA-based identification services for both public and private entities. These include such things as DNA fingerprinting of all incarcerated felons in WV, criminal and civil parentage testing, bacterial source tracking of fecal contaminants in waterways, and preservation of DNA of the deceased.

Figure 24 illustrates opportunity areas for technology development from the recommended identification, security, and sensing technology platform and also the cross-platform connectivity between the platform and other recommended platforms.

Figure 24: Identification, Security, and Sensing Technology Platform



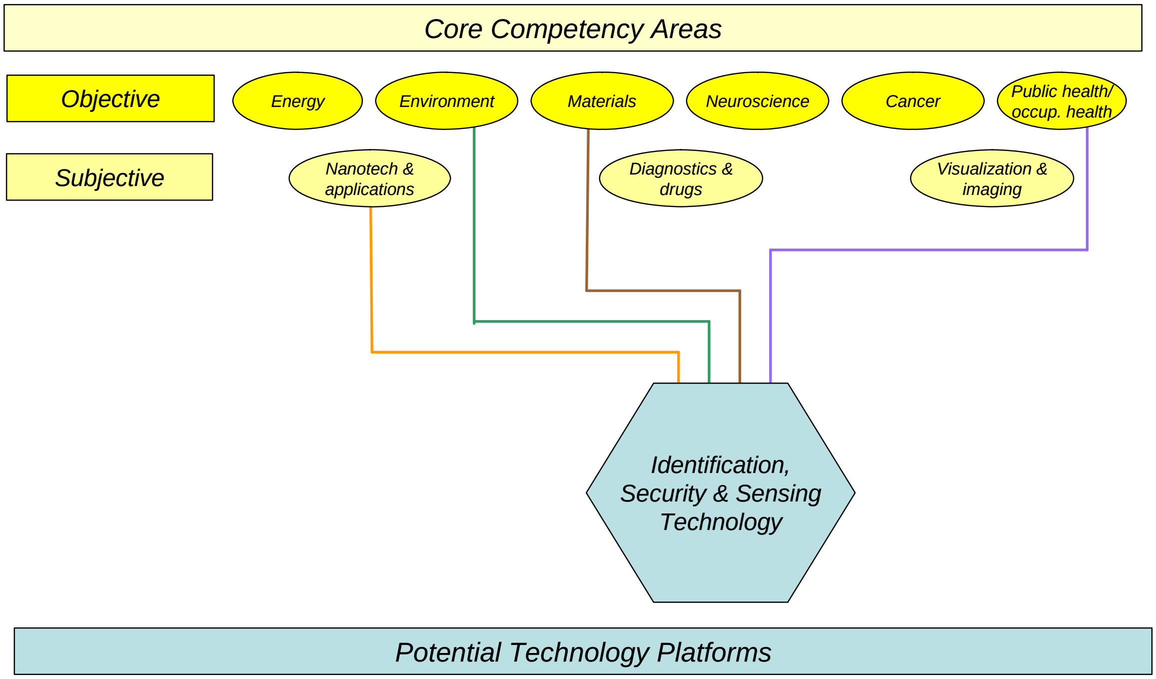
The application of potential technologies from this platform extends beyond the identification of individual humans. The advanced sensing technologies and molecular recognition technologies likely to be developed within West Virginia will have wide-ranging applications in areas as diverse as medical diagnostics and environmental monitoring.

Assessing West Virginia's R&D assets demonstrates that the identification, security, and sensing technology platform will present development opportunities along multiple technology paths, as shown in Figure 25, including the following:

- **Molecular recognition sensors**—Developing sensor components and complete sensors able to detect and characterize individual molecules for multiple applications.
- **Integrated molecular recognition systems**—Developing complete devices, systems, and sensing networks designed for security, health care, and other applications.
- **Biosensors and nano-delivery systems**—Producing R&D to develop systems for specific health care applications such as disease diagnostics and precision delivery of therapeutics via nano-based transportation devices.
- **Security and defense systems and applications**—Developing biometric tools and other identification technologies focused on government and private sector security needs
- **Environmental monitoring and sensing systems**—Leveraging molecular recognition, sensing, and nanotechnologies to develop systems for monitoring change in the environment and the introduction of pollutants/contaminants into ecosystems.
- **Electronics and nanomaterials**—Cross-linking to the advanced materials and chemicals platform to develop nanomaterials and other materials required for identification, security, and sensing technologies.

Figure 25 illustrates multiple West Virginia R&D core competencies that provide direct or indirect support to this technology platform.

Figure 25: Relationship Between Core Competencies and Identification, Security, and Sensing Technology Platform



MOLECULAR DIAGNOSTICS, THERAPEUTICS, AND TARGETED DELIVERY SYSTEMS TECHNOLOGY PLATFORM

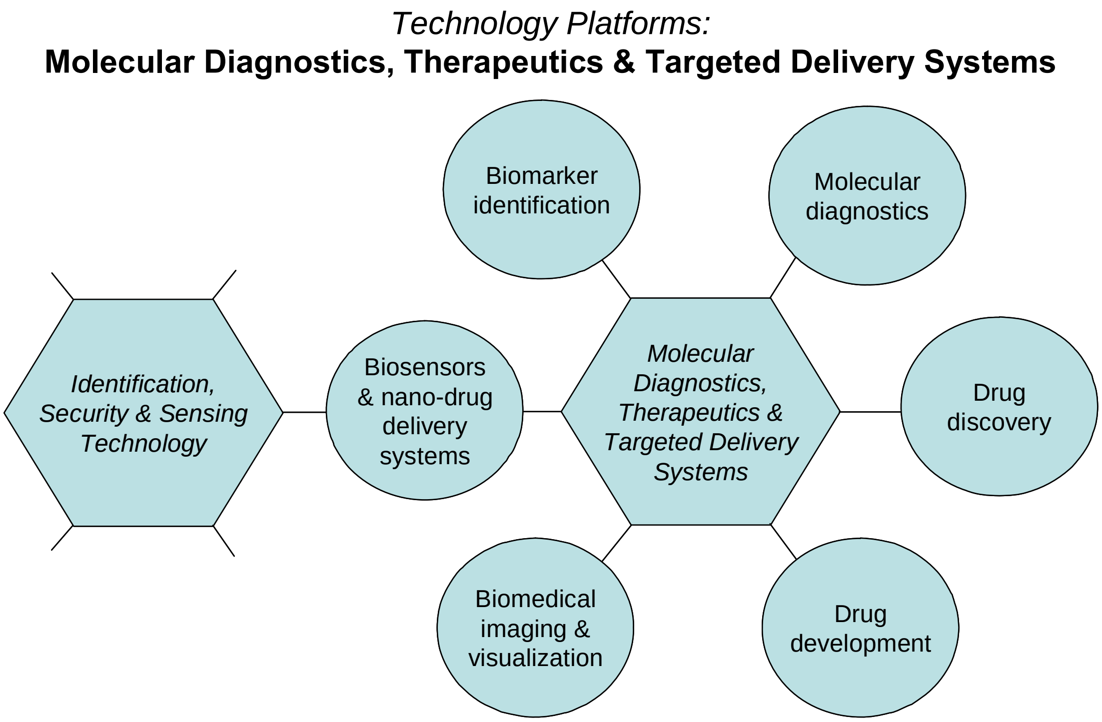
One of the key R&D growth areas within West Virginia has centered on health and life sciences. In 1997, academic life sciences R&D in West Virginia totaled $28.8 million (45 percent of total academic R&D); by 2004, this had grown substantially to $74.1 million (58 percent of total academic R&D).

Both WVU and MU have contributed to this growth, particularly within medical sciences. In terms of NIH awards between 2003 and 2006, MU received $19.4 million and WVU $52.2 million. Much of the R&D funded by these NIH awards has been focused in areas directly related to the identification of disease biomarkers and the potential development of diagnostics and therapeutics directed at these markers. Through the identification of specific molecular targets, in areas such as cancer and neurodegenerative diseases, discovery and development of novel therapeutics and diagnostic tools may then be pursued.

The development of a platform around molecular diagnostics, therapeutics, and targeted delivery systems in West Virginia could be supported not only by the academic R&D programs contained within WVU and MU, but also through building connections to the private pharmaceuticals industry in the state where there is considerable expertise in GMP production (especially, of course, at Mylan). Generally speaking, the development of this platform will require a long-term commitment because of the complex chain that must be built from basic science discovery, through advanced translational research, pilot production, clinical research and trials, and then into full production. Many elements of this vertically integrated chain are in place within West Virginia; but, key investments and coordinating activities will be required to produce a fully integrated system. The economic potential of successful development of marketable diagnostics, therapeutics, and drug delivery systems is, however, extremely large and warrants paying strong attention to development of this platform.

Figure 26 illustrates opportunity areas for technology development from the recommended molecular diagnostics, therapeutics, and targeted delivery systems technology platform and also the cross-platform connectivity between the platform and other recommended platforms.

Figure 26: Molecular Diagnostics, Therapeutics, and Targeted Delivery Systems Technology Platform



Key opportunities from this platform center on technology development in the following areas:

- **Biomarker Identification**—Producing R&D to discover new novel biomarkers for disease. This is most likely to occur in key focus areas of biomedicine in West Virginia including cancer, neuroscience, cardiovascular disease, and obesity and diabetes. Biomarkers represent patentable technology and form the basis for progress in other related technology areas.
- **Molecular Diagnostics**—Identifying biomarkers to develop specific diagnostic tools and tests to detect those biomarkers. Markets and applications for such diagnostic tools will be widespread, ranging from detecting specific cancers to determining the genotype of specific disease strains to optimize therapies.
- **Drug Discovery and Drug Development**—Identifying novel biomarkers for drug discovery, drug repurposing, and drug development aimed at positively impacting the identified targets. This requires coordination of expertise across molecular biology, pharmacology, and pharmaceutical sciences—together with clinical research.
- **Biomedical Imaging and Visualization**—Using West Virginia's core competencies in advanced biomedical imaging and visualization technologies. These technologies will feature in visualizing molecular targets and drug molecule binding sites and in imaging the effective delivery of targeted therapeutics. West Virginia has an opportunity in both the application and development of advanced imaging and visualization technologies for molecular medicine.
- **Biosensors and Nanotechnology Therapeutics Delivery Systems**—Leveraging developing biosensor and nanotechnology expertise contained within WVNano and other R&D entities within the

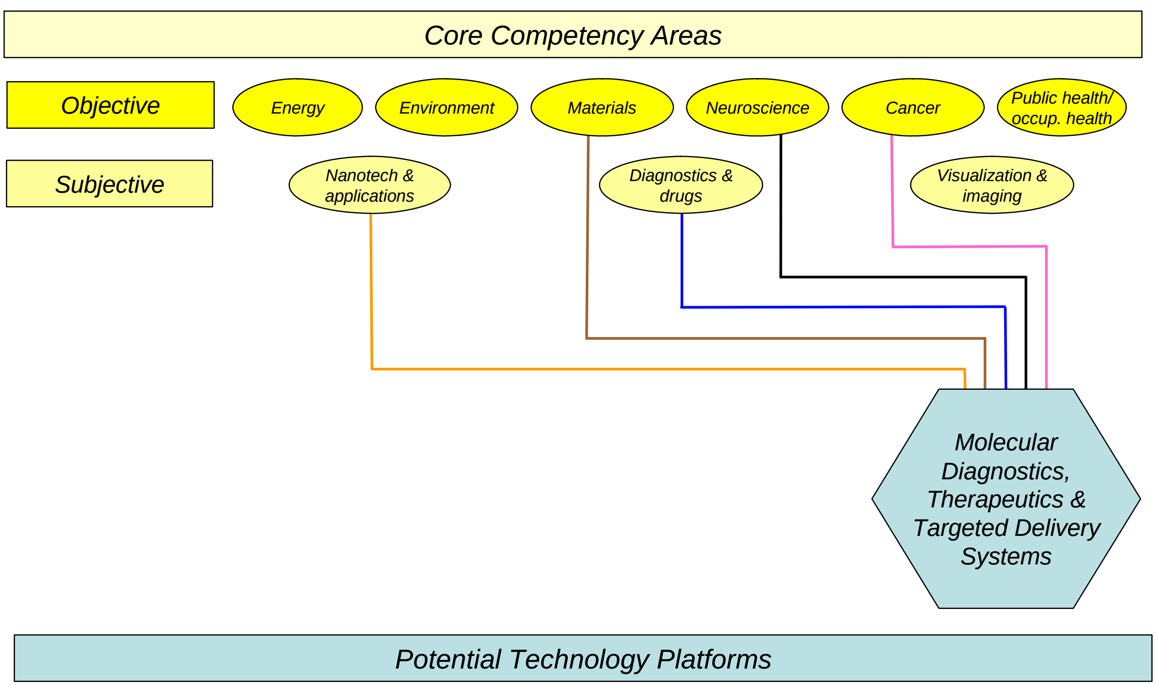
state to develop in vivo molecular diagnostic sensor devices and nanotechnology-based therapeutics carrier systems for the targeted delivery of drugs to specific molecular targets.

Successful development of this platform will very much depend on assembling multidisciplinary teams that will cross departmental and institutional boundaries. Both academic and private sector involvement will be critical to the development of commercializable technology from platform R&D. This need, in terms of the nanoscience elements alone, is highlighted in an article in the *Journal of Molecular Biochemistry*, which notes as follows:

> *Nanoscale science will play a fundamental role in imaging, biosensors, biomarkers, self-assembling tissue implants, and drug delivery over the next decade. Ironically, as devices and agents become smaller, they will require bigger and more multidisciplinary teams to realize the anticipated revolution. In contrast to the time-honored models of academic collaboration among highly focused laboratories, nanoscience efforts will require that investigators learn each other's languages and form partnerships that integrate individual intellectual components into a cohesive team approach. The complexity of the new nanotechnologies and the scope of their clinical and commercial applications require direct and immediate access to diverse ''in house'' expertise, which could dramatically impact the traditional academic paradigm for doing science.*[33]

Within West Virginia, multiple core competencies were identified that will need to be coordinated in terms of forming an interdisciplinary platform team. Figure 27 illustrates core competency connections to the platform.

Figure 27: Relationship of Core Competencies to the Molecular Diagnostics, Therapeutics, and Targeted Delivery Systems Technology Platform

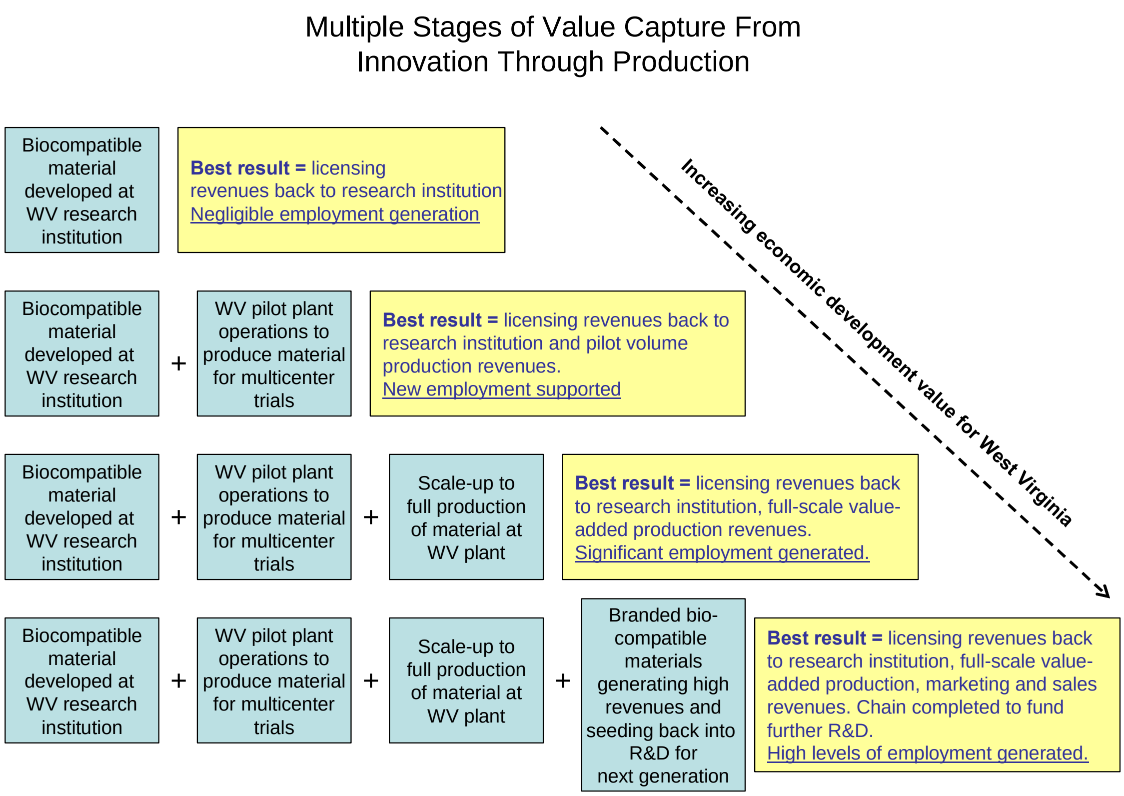


[33] Wickline, S. A., and G. M. Lanza. "Molecular imaging, targeted therapeutics and nanoscience." *Journal of Cellular Biochemistry,* Supplement 39:90–97, 2002.

MARKET ANALYSIS

The ultimate goal for West Virginia in supporting the development of technology platforms is economic development. R&D, in and of itself, ***is*** economic development in that millions of dollars flow into the state each year from federal and other external funding sources to support research. These dollars, in turn, create jobs and income for persons in the state in, and related to, the R&D sector. **The goal of technology-based economic development, however, is to move into an integrated model whereby local research feeds a local commercialization and production cluster, thereby capturing increased value-added economic gains for West Virginia from its R&D work.** Figure 28 shows the increasing returns associated with commercial development of technology R&D.

Figure 28: Increasing Economic Returns Through Production of Technology Products



Given the increasing regional economic returns through the commercialization of R&D innovations, it is highly important that platforms be developed with a view to markets and commercialization opportunities related to each platform. Tables 20 through 23 integrate R&D strength areas with applications and potential products and general market characteristics. It is evident that each of the platform focus areas addresses multibillion markets, providing considerable opportunity for growing the West Virginia economy around these technology platforms.

Table 20: Linkages of Advanced Energy and Energy-Related Technology Platform to Applications and Markets

Coal use worldwide is projected to increase by 1.7 billion short tons (36 percent) between 1999 and 2020.

Technology Platform: Advanced Energy and Energy-Related Technology	
Applications and Products	Advanced combustion technologies Alternative fuels, especially liquid fuels Fuels and materials from carbon (coal) Fuel cells and alternative power devices Combustion and engine management technology Software, modeling and simulation tools Pollution control equipment Advanced integrated transportation energy systems Energy efficiency technologies Advanced mineral resource recovery technology Tools for certification and validation Educational technology and tools "Clean" mining technology Particulate removal/reduction systems Vehicle emissions control systems Environmental clean-up/remediation technologies Detoxification agents Genetically engineered bioremediation products Monitoring, sensing and reporting technology Power plant water cooling systems Carbon management/sequestration technology
Markets	World energy consumption is projected to rise by 59% between 1999 and 2020, reaching 607 quadrillion BTUs. Coal use worldwide is projected to increase by 1.7 billion tons (36%) between 1999 and 2020. Natural gas is projected to be the fastest growing primary energy source worldwide, maintaining growth of 3.2% annually over the 1999-2020 period, more than twice as high as the rate for coal. (U.S. Department of Energy). Carbon dioxide emissions are expected to rise to 7.8 billion metric tons carbon equivalent in 2010 and to 9.8 billion metric tons by 2020 Much of the increase is expected in the developing countries, where emerging economies are expected to produce the largest increases in energy consumption, and carbon dioxide emissions are projected to grow by an average of 3.7 percent per year between 1999 and 2020. (U.S. Department of Energy). World commercial demand for fuel cell products and services—including revenues associated with prototyping and test marketing—is projected to increase sevenfold to $2.5 billion in 2009 and reach $13.5 billion in 2014. (Global Information, Inc.) The stationary air pollution control equipment market stood at $3.6 billion in 2000, up 3% from 1999. (Environmental Business journal) Diesel heavy truck and bus emissions control purchases would exceed $21 billion by 2020; more than triple the 2002 level. the combined diesel/gasoline passenger vehicle emissions control market is likely to hit $60 billion by 2020, about double that of 2002. (Diesel Fuel News)

	The overall U.S. market for next generation vehicle components (consisting of fuel cell modules, hydrogen tanks, advanced battery packs and electronic traction motor/controller units) reached $35 million in 2004, but is expected to grow at an AGR of 42% to reach $208 million by 2009. (Business Communications Company, Inc.) Nonconventional oil production is projected to grow from 1.6 million barrels per day in 2001 to 10.1 million barrels per day in 2030. This includes 6 million barrels per day from oil sands and tar sands; 2.4 million barrels per day of gas-to-liquids; and the remainder (1.7 million barrels per day) coming from oil shale, coal-to-liquids, and biofuels. (International Energy Administration)

Table 21: Linkages of Advanced Materials and Chemicals Platform to Applications and Markets

Technology Platform: Advanced Materials and Chemicals	
Applications and Products	Materials for electronics/semiconductor applications Biocompatible materials for device/implant applications Value-added coal/carbon products Value-added wood products New products for West Virginia chemicals and metals industry Chemical catalysts and industrial catalysis products Advanced materials for defense/aerospace applications Waste remediation products Construction materials Biorenewable materials Value-added resource extraction from waste Sensor materials and sensor devices
Markets	The market value of the top four types of advanced structural carbon materials is nearly $1.6 billion and is expected to rise at an average annual growth rate (AAGR) of 6.6% to $2.2 billion in 2011. Carbon foams will grow from a small base of $11 million in 2006 at an industry-leading average annual rate of 18.3%. (Electronics Industry market research and knowledge Network) Nanomaterials accounted for $9.4 billion in 2005 and over $10.5 billion in 2006, growing to about $25.2 billion by 2011 (an AAGR of 19.1% between 2006 and 2011). (source: electonics.ca publications). Biocompatible materials used in implantable medical devices currently comprise a $1 billion market. While the implantable devices market itself is a global $50 billion industry. Current major materials, including medical-grade polymers, metals, advanced ceramics, pyrolytic carbon, composites, and natural materials. End-use devices include implants, valves, grafts, pacemakers, bone repair and replacement devices, artificial organs, dental materials, drug-delivery systems, dialysis/separation/filtration systems, and catheters and stents. (source: BCC Research). Understanding the market size for traditional materials is important, since it offers an indication of the potential market for advanced materials that replace traditional materials. The market in 2006 for traditional materials comprised the following: steel $62 billion; aluminum $33 billion; plastics $137 billion; rubber $33 billion, and glasses and ceramics $95 billion. (Rensselaer Polytechnic Institute) The market for thermoplastic nanocomposites within the electrical and electronics markets is expected to be valued at $450 million by 2013 (Freedonia Group). Use in the motor vehicles market is anticipated to be worth $675 million by 2013, while use in the packaging market will approach $915 million. The global metal matrix composites market stood at $185 million in 2005. The market for nonlinear optical materials is anticipated to reach $1.66 billion by 2009 (Business Communications Company) The U.S. chemical catalyst market is expected to reach $1.2 billion in 2009. (Freedonia). The U.S. market for inorganic chemicals has grown by 2.2% since 2003 to reach a value of US$30.5 billion in 2004. (Euromonitor)

Table 22: Linkages of Identification, Security and Sensing Technology to Applications and Markets

Technology Platform: Identification, Security and Sensing Technology	
Applications and Products	National/Homeland security technologies Commercial and personal security technologies Identification protection technology Forensics tools and technologies Advanced molecular diagnostics Nano-delivery systems for vaccines/drugs/genes Photonic devices and sensors Electronic devices and sensors Commercial nanomaterials and nano-composites MEMS devices Nanokinematic devices (motors) Nanofluidic systems
Markets	The total value of the homeland security market on a global basis in 2005 was estimated to be $42.4 billion. (Civitas Group, LLC). U.S. Department of Homeland Security expenditures were estimated at $8.06 billion, other federal agency spending at $3.58 billion, U.S. state and local grant and non grant expenditures $3.8 billion, U.S. quasi-governmental spending of $1.5 billion and private sector spending of $6.5 billion. Home land security spending for the rest of the world was estimated to be $19 billion. The global market for biometrics was estimated at $946 million in 2002. It is forecast to grow at an AAGR (average annual growth rate) of 29.1% to reach nearly $3.4 billion by 2007. (Business Communications Company, Inc.) International Biometrics Industry Association statistics project sales of circa $2.2 billion in 2006. Fuji-Keizei USA specifically examined the biosensor market and estimates that the market size for worldwide biosensors at year end 2003 was about $7.3 billion. They project a growth rate of 10.4% to $10.8 billion in 2007. Nanomaterials accounted for $9.4 billion in 2005 and over $10.5 billion in 2006, growing to about $25.2 billion by 2011 (an AAGR of 19.1% between 2006 and 2011). (source: electonics.ca publications). The non-military world market for sensors is projected to reach $50.6 billion by 2008. (Intechno Consulting). Demand for chemical sensors in the United States will expand at a rapid 7.3 percent annual pace to $4.1 billion in 2009, buoyed by continued strong demand for biosensor products in the medical and diagnostic industries, and increased spending on public safety and security in the face of a potential biological or chemical terrorist attack. Other markets such as environmental monitoring and industrial processing will also experience healthy gains, though not as fast as medical and diagnostics. (Global Information, Inc.)

Table 23: Linkages of Molecular Diagnostics, Therapuetics and Targeted Delivery Systems to Applications and Markets

Technology Platform: Molecular Diagnostics, Therapeutics and Targeted Delivery Systems	
Applications and Products	Advanced diagnostics and molecular diagnostics Drug discovery Drug development Enhanced molecular targeting of drugs Drug delivery system technologies Diagnostics and drug manufacturing Biomedical imaging equipment Biomedical image enhancement/processing tech. Advanced molecular visualization technology
Markets	The global market for prescription drugs is predicted to grow between 6-7% in 2006 to a total size of $640-650 billion. (source: IMS Health). The U.S. market represents fully 43% of global pharmaceutical sales, and is expected to grow faster at between 8-9%. By 2009, the top drug categories are projected to be 1) oncology ($55 billion), 2) cholesterol ($38 billion), 3) antidepressants ($26 billion), 4) stomach ulcer treatments ($26 billion), 5) hypertension drugs ($24 billion), 6) antipsychotics ($20 billion), 7) platelet inhibitors ($18 billion), 8) anemia drugs ($18 billion), 9) osteoporosis ($16 billion), and 10) anti-epileptics ($15 billion). (source: IMS Health). Molecular diagnostics markets overlap with markets for non-molecular diagnostic technologies in the in vitro diagnostic market and are less well defined than those for pharmaceuticals. In the year 2005, the global market for molecular diagnostics was worth $6.5 billion, representing approximately 3.3% of the total diagnostics market and approximately 14% of the in vitro diagnostic market. (source: Jain PharmaBiotech 2006) The molecular diagnostics market will expand to $12 billion by 2010 and $35 billion by 2015. A major portion of it can be attributed to advances in genomics and proteomics. Biochip and nanobiotechnology are expected to make a significant contribution to the growth of molecular diagnostics. (source: Jain PharmaBiotech 2006) The market for cancer treatments in the United States is currently $1.65 billion and is growing by 10% per annum. Cancer drug sales worldwide are projected to reach $55 billion in 2009, compared to the $24 billion in 2004. (source: IMS Health). In 2004, the top 20 cancer drugs in each of the seven major pharmaceutical markets generated combined sales exceeding $27 billion. The world market for non-psychiatric neurotherapeutics stood at $70 billion in 2002, according to the study, but steady growth in demand and product introduction will result in markets in excess of $88 billion by 2010. (source: Kalorama Information) The overall U.S. imaging equipment and auxiliary products market was estimated to be $7.9 billion in 2004 and is expected to increase at a 5.7% average annual growth rate to reach $10.4 billion by 2009. (source: BCC Research)

Conclusion

West Virginia is at a critical juncture in the development of its economy. The vision of a number of the state's public and private leaders has created multiple technology assets, in the form of federal and nonprofit R&D organizations, on which to build a knowledge-driven economy. Both MU and WVU are developing R&D programs that could become key drivers of the state's economy both in their respective regions and statewide. The state has growing technology industry sectors and a small cadre of technology-based start-up companies.

But, the state's technology economy is still young and must be nurtured. This will require continued investment in WVU and MU to enable them to build critical mass in key areas of research. It also will require greater industry-university collaboration, a focus on commercialization, and technical and financial support for entrepreneurs and start-up and emerging technology companies. In addition, West Virginia must grow, retain, and attract talent from world-class researchers to senior management to skilled technicians. Also, the state will need to tell both the world and its own citizens that West Virginia is changing; West Virginia is building a 21st century economy.

With the right investments, West Virginia could become a leader in the following four technology platforms identified by this analysis:

- Advanced Energy and Energy-Related Technology
- Advanced Materials and Chemicals
- Identification, Security, and Sensing Technology
- Molecular Diagnostics, Therapeutics, and Targeted Delivery Systems.

West Virginia can achieve economic development around these technology areas by building on its existing base; but, the time to act is now. West Virginia is behind many of its peer and competitor states. The state's public and private sectors need to come together and commit to taking the actions needed to compete in these areas.

West Virginia through Vision Shared and *Vision 2015* has done an excellent job of setting out a vision for the state's future and assessing the challenges it faces in achieving that vision. This analysis is the first step in preparing a blueprint that will outline specific strategies and actions to expand these technology platforms, address gaps in West Virginia's technology infrastructure, and accelerate the growth of the state's technology sectors. Completion of the Blueprint and an Implementation Plan for moving forward will help ensure that West Virginia achieves its vision of being a leader in innovation-led economic development.

Appendix A: Detailed Descriptions of Core Competency Areas

Key findings for each of the core competency areas are detailed on the pages that follow, with each area summarized in terms of:

- A definition of the field or specialty area
- A general profile of the sub-disciplinary strengths evident in the state of West Virginia
- Supporting quantitative statistics (where available)
- Details regarding the strengths in West Virginia that were identified by interviewees.

Table A-1: Energy

Energy		
Overview		Energy is used here to define fields of science, technology and engineering related to the continuum of energy-science, including: fossil energy resource extraction (mining and drilling operations); energy production from fossil resources; energy production via alternative and renewable technologies; energy transportation and transmission; energy use and efficiency of use; and environmental aspects of energy production and use.
Presence in Cluster Analysis		"Coal-related technologies" metacluster 81 grants, 4 patents "Fuel Cells" metacluster 20 grants, 4 patents "Oil and petroleum related technologies" metacluster 36 grants, 3 patents "Well drilling/boring technologies" metacluster 17 grants, 52 patents.
Competitive Position	Research Funding	Federal funding data shows West Virginia performing more engineering R&D as a percentage of its total R&D than would be expected given the state's size.
	Publications & Patent Analysis	Spread across multiple science and engineering disciplines. "Environmental Engineering and Energy" with 46 papers and a publications quotient of 1.40. 36 patents in "wells" and 22 in "boring or penetrating the earth".
	Major Funded Centers or Programs	• National Energy Technology Laboratory (federal lab) • National Research Center for Coal and Energy • Advanced Power and Electricity Research Center • Research Center for Alternative Fuels, Engines and Emissions • West Virginia Industries of the Future • Coal and Energy Research Bureau • Longwall Mining and Ground Control Research Center
Insights from and Niches Identified from Interviews		National Energy Technology Laboratory – Historic strengths in advanced coal combustion, gasification, natural gas, and hot gas clean-up technology

	– R&D focused in: – Advanced combustion control and simulation – Carbon management technologies – Advanced materials processing and development – Predictive computational tools, modeling and simulation – Enabling technologies for extreme deep resource development – Energy delivery and infrastructure security – WVU – Fossil fuels, especially coal (+natural gas and petroleum) – Alternative fuels, non-petroleum based liquid fuels – Pollution control – Advanced oil and gas recovery – Vehicle powerplant efficiency and integrated vehicle power systems – Testing, validation, certification and training – Energy efficiency for industry – Potential to link in transportation modeling and simulation and rail-related R&D at Marshall Of Note • Broad base of scientific expertise across multiple institutions • Multiple convergence technology opportunities • Developing collaboration of NETL-WVU-Pitt-CMU • Differentiated from other states which are predominantly focusing on biorenewables

Technology Opportunity Examples: Environment
• Advanced combustion technologies • Alternative fuels, especially liquid fuels • Fuels and materials from carbon (coal) • Combustion and engine management technology • Software, modeling and simulation tools • Pollution control equipment • Advanced integrated transportation energy systems • Energy efficiency technologies • Advanced mineral resource recovery technology • Tools for certification and validation • Educational technology and tools

Table A-2: Environment

<table>
<tr><th colspan="3">Environment</th></tr>
<tr><td colspan="2">Overview</td><td>Environmental science is the science of the interactions between the physical, chemical, and biological components of the environment, including their effects on all types of organisms. Ecology is the branch of biology concerned with the relations between organisms and their environment. In West Virginia much of the R&D being performed is related to human impacts on the environment and ecosystems (impact prevention, impact reduction and environmental restoration).</td></tr>
<tr><td colspan="2">Presence in Cluster Analysis</td><td>1 cluster “soil remediation” with 12 grants and 1 patent.</td></tr>
<tr><td rowspan="3">Competitive Position</td><td>Research Funding</td><td>$7.2 million in academic R&D expenditures across West Virginia higher education institutions.</td></tr>
<tr><td>Publications & Patent Analysis</td><td>Primary publication strength with 164 papers in Environment/Ecology published between 2001 and 2005; papers quotient of 1.55 and citations quotient of 2.01. 38 papers in “environmental studies, geography and development” with papers quotient of 2.31 and citations quotient of 2.52.</td></tr>
<tr><td>Major Funded Centers or Programs</td><td>Component in terms of pollution prevention and control, environmental restoration and other environmental programs within major energy research institutes cited on Table __.
National Mine Land Reclamation Center
West Virginia Water Research Institute
National Environmental Training Center for Small Communities</td></tr>
<tr><td colspan="2">Insights from and Niches Identified in Interviews</td><td>Core Strengths
Pollution prevention and reduction technologies
Mining, Energy Production, Vehicles
Environmental remediation technology
Water, Soil, Phytoremediation
Environmental genetics and genomics
Environmental health
Toxicology and Public Health
Of Note
Broad base of scientific expertise across multiple institutions
Multiple convergence technology opportunities
Key focus within universities, especially WVU and MU
Directive focus area of NETL
MATRIC focus in environmental technology
Marshall University environmental research taking place across multiple units, including: CEGAS (the Center for Environmental, Geotechnical and Applied Science); the Forensic Science Center (in bacterial source tracking in waterways); the College of Science and the Rahall Transportation Institute.</td></tr>
</table>

Technology Opportunity Examples: Environment
• "Clean" mining technology • Value-added resource extraction from waste • Particulate removal/reduction systems • Vehicle emissions control systems • Energy efficiency technology • Clean-up/remediation technologies • Detoxification agents • Genetically engineered bioremediation products • Monitoring, sensing and reporting technology • Testing, validation and certification tools • Power plant water cooling systems • Carbon management/sequestration technology

Table A-3: Materials

<table>
<tr><th colspan="3">Materials</th></tr>
<tr><td colspan="2">Overview</td><td>This category is best defined as “advanced materials and chemicals”, comprising new R&D-based chemicals and materials, or technologically enhanced chemicals or materials. Within West Virginia much research is focused on advanced applications of fossil-resource based materials.</td></tr>
<tr><td colspan="2">Presence in Cluster Analysis</td><td>“Chemicals and catalysts” metacluster 93 grants, 370 patents

“Composites and advanced materials” metacluster 39 grants, 85 patents

“Polymers” metacluster 16 grants, 170 patents</td></tr>
<tr><td rowspan="3">Competitive Position</td><td>Research Funding</td><td>$5.4 million in academic R&D expenditures across West Virginia institutions in “metallurgical and materials engineering” for 2004. $5 million in “chemical engineering”.</td></tr>
<tr><td>Publications & Patent Analysis</td><td>Primary publication strength with 153 papers in “applied physics/condensed matter/materials science” with citations quotient of 1.28. 78 papers in “materials science and engineering”. 49 papers in “chemical engineering” with publications quotient of 2.16 and citations quotient of 2.64. 72 papers in “organic chemistry/polymer science” with publications quotient of 1.22 and citations quotient of 2.0.

236 patents in “synthetic resins or natural rubbers”, 25 patents in “organic compounds” and 37 patents in “catalyst, solid sorbent, or support”.</td></tr>
<tr><td>Major Funded Centers or Programs</td><td>• Asphalt Technology Center WVU in collaboration with the West Virginia Flexible Pavements Council and West Virginia-DOT)
• Component in terms of carbon-based materials within major energy research institutes cited on Table __.</td></tr>
<tr><td colspan="2">Insights from and Niches Identified in Interviews</td><td>• Core Strengths
o Electronic materials
o Sensor materials, semiconductor materials
o Composite materials
o Bio-composites, polymer composites
o Catalysts and catalytic materials
o Carbon Products
o Foams, anodes, casting materials
o Value-added wood products
o Nano and nanobio materials
o Bio-compatible polymers and advanced materials
o Value-added materials from mine, power generation and other waste streams
• Of Note
o Key strength across multiple engineering and physical science disciplines at WVU
o Partial focus are for NETL
o Opportunity for advanced applications for basic West</td></tr>
</table>

	Virginia products (wood, coal, etc.) o Charleston-MATRIC expertise in chemicals and associated engineering. Strong infrastructure.

Technology Opportunity Examples: Materials
• Sensor materials and sensor devices • Materials for electronics/semiconductor applications • Biocompatible materials for device/implant applications • Value-added coal/carbon products • Value-added wood products • New products for West Virginia chemicals and metals industry • Chemical catalysts and industrial catalysis products • Advanced materials for defense/aerospace applications • Waste remediation products • Construction materials • Biorenewable materials

Table A-4: Neurosciences

Neurosciences		
Overview		Neuroscience is the study of how the brain and nervous system work. Neuroscience integrates more traditional scientific approaches such as anatomy, physiology, and biochemistry, along with newer fields such as molecular biology and computer science, to understand how the nervous system functions.
Presence in Cluster Analysis		"Drugs, diagnostics, therapies" metacluster with 193 grants and 19 patents.
Competitive Position	Research Funding	$40.5 million in academic R&D expenditures across West Virginia institutions in "medical sciences" for 2004.
	Publications & Patent Analysis	58 papers in "neurology" with publications quotient of 1.21 and citations quotient of 1.39. 158 papers in "neurosciences & behavior"
	Major Funded Centers or Programs	• Center for Neuroscience (WVU)—programs in sensory, cognitive, and behavioral neuroscience, along with studies of cellular responses to injury, neuroendocrinology, and autonomic control of feeding and respiration. • Eye Institute (WVU)—vision neuroscience.
Insights from and Niches Identified in Interviews		• Core Strengths o Sensory neuroscience o Sensory Neurosciences Research Center o Eye Institute o Cognitive neuroscience/memory o Neurodegeneration and degenerative diseases o Focus of Blanchette Rockefeller Neurosciences Institute o Alzheimer's R&D o Neuroimaging o Imaging technology and image processing o Behavioral neuroscience o Major psychology R&D initiatives across multiple institutions o Neurological and psychiatric disorders o Growing emphasis on stroke, epilepsy and depression o Strong clinical practices in related disciplines • Of Note o Major infrastructure and personnel investments at WVU o Strong translational research focus of BRNI o Diagnostic and drug development support through pharmacy, pharmacology and MCB resources

Technology Opportunity Examples: Neuroscience
• Biomarker identification and associated IP • Advanced diagnostic tests • Implantable sensors and stimulation devices • Drugs and therapeutics • Genetics testing and therapies • Neuroimaging technology and imaging agents • Advanced clinical diagnostic and treatment services

Table A-5: Cancer

Cancer		
Overview		Cancer is a class of diseases or disorders characterized by uncontrolled division of cells and the ability of these cells to spread, either by direct growth into adjacent tissue through invasion, or by implantation into distant sites by metastasis (where cancer cells are transported through the bloodstream or lymphatic system).
Presence in Cluster Analysis		"Drugs, diagnostics, therapies" metacluster with 193 grants and 19 patents.
Competitive Position	Research Funding	$40.5 million in academic R&D expenditures across West Virginia institutions in "medical sciences" for 2004.
	Publications & Patent Analysis	99 papers in "oncogenesis and cancer research" with publications quotient of 1.37 and citations quotient of 1.57. 39 papers in "oncology".
	Major Funded Centers or Programs	• Mary Babb Randolph Cancer Center (WVU)
Insights from and Niches Identified in Interviews		• Core Strengths o Mary Babb Randolph Cancer Center ▪ Basic Science Research • Cancer cell biology • Signaling networks • Tumor microenvironment • Molecular therapeutics ▪ Population Research • Health services and intervention • Translational tobacco reduction ▪ Clinical Research • Cancer prevention and control • Breast cancer • Cervical cancer • Colorectal cancer • Prostate cancer • Lung cancer • Hematological malignancies • Pain management o Marshall University COBRE award. R&D focus in melanoma and in effects of nutrition on cancer. Basic science research in cancer genetics, epigenetics and nutrition. ▪ *MU with 117 active clinical research protocols*

	in cancer (predominantly large Phase II and II trials) • Of Note o Major new infrastructure and personnel investments at WVU. Major investment in the WVU Cancer Center and recent construction of $39 million Joan C. Edwards Cancer Center at Marshall, with top floor dedicated to translational research. o R&D/publications strengths noted at MU and WJ o Primary focus for growth at MU o Diagnostic and drug development support through pharmacy, pharmacology and MCB resources

Technology Opportunity Examples: Cancer
• Sensor materials and sensor devices • Materials for electronics/semiconductor applications • Biocompatible materials for device/implant applications • Value-added coal/carbon products • Value-added wood products • New products for West Virginia chemicals and metals industry • Chemical catalysts and industrial catalysis products • Advanced materials for defense/aerospace applications • Waste remediation products • Construction materials • Biorenewable materials

Table A-6: Public Health and Occupational Health and Safety

Public Health and Occupational Health and Safety		
Overview		Public health addresses the health of the population as a whole rather than medical health care, which focuses on treatment of the individual ailment. According to the Institute of Medicine, the mission of public health is defined as "fulfilling society's interest in assuring conditions in which people can be healthy". Occupational health and safety involves R&D and actions undertaken to prevent work related injuries and illnesses.
Presence in Cluster Analysis		No specific cluster evident
Competitive Position	Research Funding	• NIOSH Morgantown R&D center with $36.1 million budget. • WVU with $1.2 million in public health research from NIH
	Publications & Patent Analysis	42 papers in "environmental medicine and public health" with publications quotient of 1.38 and citations quotient of 1.69. 31 papers in "health care sciences 7 services" with publications quotient of 1.72 and citations quotient of 1.96.
	Major Funded Centers or Programs	• National Institute of Occupational Safety and Health (NIOSH)—Morgantown Center • WVU Institute for Occupational and Environmental Health • Prevention Research Center • Generic Mineral Technology Center for Respirable Dust • Center on Aging
Insights from and Niches Identified in Interviews		• Core Strengths o Morgantown a major R&D center for NIOSH (National Institute of Occupational Safety and Health) 369 FTEs, $36.1 million budget. R&D focus areas: ▪ Division of Safety Research (DSR) (traumatic occupational injury research) ▪ Division of Respiratory Disease Studies (DRDS) (identification, evaluation, and prevention of occupational respiratory disease, such as asthma, chronic obstructive pulmonary disease, and pneumoconiosis) ▪ Health Effects Laboratory Division (causes and mechanisms of occupational injury and health effects) ▪ Expertise in epidemiology, industrial hygiene, immunology, occupational medicine, chemistry, engineering and statistics o WVU Institute for Occupational and Environmental Health o Graduate program in public health at WVU ▪ Rural health expertise ▪ Focus on epidemiology/spatial analysis of

	Appalachian diseases • Of Note o Direct link to multiple other R&D focus areas in: o Environmental science o Cancer and neurodegenerative disease o Toxicology and pharmacology o Other disease areas such as respiratory diseases and infectious diseases o Diagnostic and drug development support through pharmacy, pharmacology and MCB resources

Technology Opportunity Examples: Public Health and Occupational Safety and Health
• Sensors and monitoring systems • Occupational safety/protection technologies • Sanitation and hygiene technology • Advanced diagnostic and laboratory tests • Investigational tools and technologies (e.g. GIS) • Advanced clinical services

Table A-7: Nanotech Devices and Sensors

Nanotech Devices and Sensors		
Overview		Nanotechnology involves technology development at the atomic, molecular, or macromolecular range of approximately 1-100 nanometers to create and use structures, devices, and systems that have novel properties. A sensor is an electronic, biological or mechanical device used to measure a physical quantity such as temperature, pressure or loudness and typically convert it into an electronic signal.
Presence in Cluster Analysis		"Instruments, controls and electronics" metacluster with 29 grants and 122 patents. "Information and communications technology" metacluster with 49 grants and 18 patents.
Competitive Position	Research Funding	$38 million in academic R&D expenditures across West Virginia institutions in all engineering disciplines for 2004.
	Publications & Patent Analysis	No specific ISI category for nanotechnology or sensors.
	Major Funded Centers or Programs	• WVNano Initiative • National Biometric Security Project (NBSP)—see description in Table __. • Microelectronic Systems Research Center
Insights from and Niches Identified in Interviews		• Core Strengths WVNano Initiative o WVNano's focus is on bringing together the semiconductor device and biomolecular worlds to explore <u>integrated molecular recognition systems</u> capable of rapidly detecting biomolecular species for health and security applications. Broad base of scientific expertise across multiple institutions o Targeting development of chip-level integrated recognition systems capable of rapid and renewable direct detection of molecular targets o Home to CITeR, the Center for identification Technology Research (the only NSF Center in physiological biometrics) o Logical extension of security molecular recognition work across into health sciences for diagnostics applications in focus areas such as cancer and neurological disease o Link to forensic science concentration within WVU for molecular forensics and Marshall in forensics and genetic analysis • Of Note: o Major investment through $9 million NSF EPSCoR Research Infrastructure and additional state EPSCoR funds of $4 million. Plus additional commitment from WVU of $8 million. Funded development of nano/micro engineering clean room facilities and

	associated R&D/engineering infrastructure, and the recruitment of faculty/scientific personnel at WVU and Marshall. o Broad base of scientific expertise at the bio-nano interface at WVU and Marshall.

Technology Opportunity Examples: Nanotech Devices and Sensors
• National/Homeland security technologies • Commercial and personal security technologies • Identification protection technology • Advanced molecular diagnostics • Nano-delivery systems for vaccines/drugs/genes • Forensics tools and technologies • Photonic devices and sensors • Electronic devices and sensors • Commercial nanomaterials and nano-composites • MEMS devices • Nanokinematic devices (motors) • Nanofluidic systems

Table A-8: Security and Identification Technology

Security and Identification Technology (Biometrics)		
Overview		Biometrics is the science of using biological properties to identify individuals; for example, fingerprints, retina scan and voice recognition.
Presence in Cluster Analysis		“Instruments, controls and electronics” metacluster with 29 grants and 122 patents. “Information and communications technology” metacluster with 49 grants and 18 patents. “Cellular and molecular biology” metacluster with 162 grants and 30 patents.
Competitive Position	Research Funding	$38 million in academic R&D expenditures across West Virginia institutions in all engineering disciplines for 2004.
	Publications & Patent Analysis	No specific ISI category for security and identification technology.
	Major Funded Centers or Programs	• NSF Center in Physiological Biometric recognition (CITeR) • National Biometric Security Project (NBSP) • WVNano Initiative • Department of Defense Biometrics Fusion Center (Bridgeport), this is the test and evaluation facility for the DoD Biometrics Management Office (BMO). • FBI Criminal Justice Information Services Division (CJIS)
Insights from and Niches Identified in Interviews		• Opportunities along both near-term and long-term time horizons. Substantial opportunity to tie together resources in north central West Virginia in terms of NBSP, the FBI, DoD Biometrics Fusion Center, and WVU for work in a broad range of biometrics and secure identification technologies and applications. • National Biometric Security Project (NBSP) is a non-profit organization with major operation in Morgantown housing NBSP’s Test, Research and Data Center. Organized with four divisions: o Test & Evaluation Division—testing biometric products against documented performance criteria o Training & Education Services Division—working with industry, academic institutions and others to establish curricula and provide in-depth training and certification courses o Data Services Division—Storing and distributing data on biometrics solutions, and providing specialized data services for customers o Research and Acquisition Support Services Division—conducting novel research programs on new biometric technology, applications of biometrics, and social impacts. Direct assistance to customers with vulnerability assessment, technology evaluation, deployment and operational support. • Home to CITeR, the Center for identification Technology Research (the only NSF Center in physiological biometrics). This is an NSF Industry/University Cooperative Research Center. CITeR “serves members by advancing the performance of biometric systems

	through cross-cutting research of new enabling technologies, interdisciplinary training of scientists and engineers through its biometrics research, and the facilitation of the transfer of new biometrics technology to the private and government sectors through its membership." R&D work is focused in: biometric sensing and analysis; biometric system statistical design and evaluation, and biometrics in information assurance. CITeR also works on business/economic issues and legal/policy issues in regards to biometrics. • The DoD Biometrics Fusion Center conducts work on biometrics technology and applications suitable for the mobile and extreme environment operational needs of the U.S. armed forces. The BFC conducts work in technology and application testing and evaluation, maintains a knowledge base on biometrics and biometrics technology, provides technical expertise to the DoD and provides the industry and academic R&D interface in biometrics for the DoD. • The FBI CJIS hosts the National Crime Information Center, including its Brady Act gun check headquarters, its Uniform Crime Reports data center, and its Integrated Automated Fingerprint Identification System. • Marshall University is home to the Forensic Sciences Center created in 1994 by the U.S. Department of Justice. • WVU offering the world's first degree programs in forensic identification, with emphasis in biometrics and latent fingerprint identification. • It was noted in interviews that major federal legislation will be driving major demand for biometrics technology in the near-term. The President signed an order, for example, requiring all federal employees and contractors to have a biometric ID card by 2007 (covering 9 million persons). The federal Real ID act will require all states to have biometric enabled identification checks and to have the capability to cross-check identification from one state to another. • I-79 Council is working on a Biometrics Initiative which aims to pull together all of the key resources in biometrics in the north central West Virginia region into a consortia. Such a consortium will enable the region to provide a broad suite of services and technologies, and to bring together key parties, to work on securing large-scale biometrics contracts.

Technology Opportunity Examples: Security and Identification Technology
• National/Homeland security technologies • Commercial and personal security technologies • Identification protection technology • Forensics tools and technologies

Table A-9: Diagnostics and Drugs

<table>
<tr><th colspan="3">Diagnostics and Drugs</th></tr>
<tr><td colspan="2">Overview</td><td>This includes discovery and development of diagnostics and therapeutics for human biomedical use.</td></tr>
<tr><td colspan="2">Presence in Cluster Analysis</td><td>“Drugs, diagnostics and therapies” metacluster with 193 grants and 19 patents. “Cellular and molecular biology” metacluster with 162 grants and 30 patents.</td></tr>
<tr><td rowspan="3">Competitive Position</td><td>Research Funding</td><td></td></tr>
<tr><td>Publications & Patent Analysis</td><td>163 papers in “pharmacology & toxicology” with publications quotient of 2.31 and citations quotient of 2.85.

21 patents in “drug, bio-affecting and body treating compositions”</td></tr>
<tr><td>Major Funded Centers or Programs</td><td>• Mary Babb Randolph Cancer Center
• Center for Neuroscience</td></tr>
<tr><td colspan="2">Insights from and Niches Identified in Interviews</td><td>Core Strengths
• West Virginia has a base of companies engaged in the pharmaceuticals and diagnostics sector
• Cancer R&D initiative at WVU in molecular therapeutics
• Potential for advanced, molecular targeted delivery systems via WVNano Initiative
• WVU R&D programs in:
– Anti-cancer drug discovery
– Drug-receptor interactions
– Computational Chemistry and Molecular Modeling
– Drug Delivery and Pharmaceutical Technology
– Medicinal Chemistry
– Drug Metabolism and Pharmacokinetics
• Marshall engaged in drug repurposing studies for cardiovascular and diabetes applications
• Of Note:
• Therapeutics production capability and expertise within West Virginia
• Translational therapeutics focus in cancer, neurological diseases and other specific health areas.</td></tr>
</table>

Technology Opportunity Examples: Diagnostics and Drugs
• Advanced diagnostics and molecular diagnostics • Drug discovery • Drug development • Enhanced molecular targeting of drugs • Drug delivery system technologies

• Diagnostics and drug manufacturing

Table A-10: Visualization and Imaging

<table>
<tr><th colspan="3">Visualization and Imaging</th></tr>
<tr><td colspan="2">Overview</td><td>Visualization is process associated with computational science to represent as graphic images quantitative data or the results of complex simulation computations. It aims to give the data a meaningful representation by exploiting the powerful discerning capabilities of the human eye. The data is displayed as 2D or 3D images using techniques such as colorization, 3D imaging, animation and spatial annotation to create an instant understanding from multi-variable data. Virtual reality is one a form of visualization. Imaging, as a term is generally applied to the use of non-invasive scanning techniques for developing images of the inside of living organisms.</td></tr>
<tr><td colspan="2">Presence in Cluster Analysis</td><td>“Imaging” metacluster with 22 grants and 9 patents. “Instruments, controls and electronics” metacluster with 29 grants and 122 patents. “Information and communications technology” metacluster with 49 grants and 18 patents.</td></tr>
<tr><td rowspan="3">Competitive Position</td><td>Research Funding</td><td></td></tr>
<tr><td>Publications Analysis</td><td>54 papers in “radiology, nuclear medicine and imaging” with publications quotient of 1.30 and citations quotient of 2.56.</td></tr>
<tr><td>Major Funded Centers or Programs</td><td>• West Virginia Virtual Environments Laboratory
• Center for Advanced Imaging (WVU College of Medicine Department of Radiology)
• NSF/EPSCoR Medical Imaging and Image Processing Research Cluster</td></tr>
<tr><td colspan="2">Insights from and Niches Identified in Interviews</td><td>• Core Strengths
– West Virginia EPSCoR/WVU Department of Computer Science and Electrical Engineering created Virtual Environments Laboratory
- Working in vision, sound, haptics, and the integration of multiple senses in virtual environments
- Working on both technology and applications development
- Projects in pharmaceuticals design, materials development, civil engineering, rehabilitation and education
- Resources actively being used by researchers at multiple West Virginia institutions
– Additional visualization technology at NIOSH
– Marshall University developing visualization lab in new engineering building. Sophisticated array of powerful microscopes in newly created Molecular and Biological Imaging Center within the new Biotechnology Science Center (BSC)</td></tr>
</table>

	– Geographic Information Systems (GIS) and Geo-visualization systems at WVU - GeoVirtual Laboratory (immersive GIS) - National Geospatial Development center (current focus on disaster response and on soil) - Health science and epidemiology applications of GIS - West Virginia State GIS Technical Center within WVU Department of Geography – WVU Health Sciences Center home to the Center for Advanced Imaging conducting research in: - Imaging instrumentation - Neuro-imaging - Magnetic Resonance Imaging (MRI) physics – Supercomputing Consortium providing high-performance computing access

Technology Opportunity Examples: Visualization and Imaging
• Advanced visualization technology • Visualization image processing tools/software • Customized GIS applications and technology • Public health and epidemiology tools • Biomedical imaging equipment • Biomedical image enhancement/processing tech.